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ABSTRACT

This publication provides background information and activity suggestions on air pollution and related environmental topics. Student projects and experiments which can be adapted at both elementary and secondary levels are also provided. Information is organized in three parts. Part I covers basic facts about air pollutants including the types, forms, and sources of the pollutants. Part II discusses the effects of specific pollutants and explains how these effects are studied. Behavioral objectives and test items with answers are provided for the teacher in the first two units. Part III contains supplemental information and additional student experiments and activities. Experiments in this section address meteorological aspects, human health factors, vegetation cases, and pollution control problems. Each experiment is formulated with: (1) an educational objective; (2) a materials list; (3) procedures; (4) a results section; and (5) discussion questions. (ML)

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SOURCE BOOK ON AIR POLLUTION TOPICS

for

Grade and High School Teachers

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Air Pollution Control Association

SOURCE BOOK ON AIR POLLUTION TOPICS
for
Grade and High School Teachers

PART I — Air Pollutants and Their Sources

PART II — Effects of Air Pollution
Adapted from APTI Course SI:422
U.S. Environmental Protection Agency

PART III — Air Pollution Workbook
Prepared by Carol Wirth Wolff
Commissioned by
the Mid-Atlantic States Section of
the Air Pollution Control Association

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P.O. Box 2861
Pittsburgh, PA 15230

FOREWORD

This publication is aimed at providing background information on air pollution to teachers of environmental topics in grade and high schools and at outlining student projects in this area. It consists of three sections. Part I covers basic facts about air pollutants and their sources while Part II discusses the effects of air pollution. The final section, Part III, provides additional information and suggests experiments and activities for students to carry out to further their understanding of the air they breathe.

ACKNOWLEDGMENTS

Regarding Parts I and II, we are thankful to R. E. Townsend, the EPA Project Officer for the development of APTI Course SI:422 from which these parts were adapted, and his associate, Charles Pratt, for their cooperation and assistance. The complete self-instructional course is made up of nine units. Two units are in text form and seven units are in flipbook form with an accompanying audio tape. Information on Course SI:422 can be obtained from:

United States Environmental Protection Agency
Manpower and Technical Information Branch
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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Part III, which was developed first, represents the earnest and continued commitment of MASS APCA to the education of young students. As a function of the Education Committee and with the support of the Executive Committee, Carol W. Wolff, a former Secretary of MASS APCA and Chairman of the Education Committee, coordinated the material and developed activities and experiments that provide exciting and informative experience. Among the many Education Committee members who contributed to either the development or testing of the Workbook were Mrs. Linda Burns, Mrs. Ada Flower, Professor Ida Leone, Dr. Vincent Marchesani, Mrs. Sara Siebert, Mr. Terry Silpe, Dr. Joseph Soporowski, and Dr. George Wolff. We also gratefully acknowledge Ms. H. Lorraine Yock for her technical assistance in the final production of the Workbook.

Finally, we wish to thank the Society for Analytical Chemists of Pittsburgh and the Spectroscopy Society of Pittsburgh for their grants to aid in the publication of this Source Book.

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PART I

Air Pollutants and Their Sources

Lesson I: Air Pollutants

Objectives

1. Identify the two basic physical forms of air pollution.
2. Explain how a secondary pollutant is formed.
3. Match the names of the criteria pollutants with their descriptions and their major sources.
4. State two differences between hazardous pollutants and criteria pollutants.

Two Basic Physical Forms of Air Pollution

Particles

- small, discrete masses of solid or liquid matter
- examples: dust, smoke, mists, and fly ash

Gases

- widely separated molecules in rapid motion
- lack definite shape and volume
- examples: carbon monoxide, sulfur dioxide, & hydrocarbon vapors

Primary Pollutants

- emitted into atmosphere directly from identifiable sources
- found in atmosphere in same chemical form as when emitted from source

- undergo chemical changes in the atmosphere as a result of reactions among two or more pollutants

Secondary Pollutants

National Ambient Air Quality Standards (NAAQS)

- Set for **criteria pollutants**—widespread, common pollutants shown to be harmful to human health and welfare
- Designed to meet two goals
  - protect human health & well-being
  - prevent undesirable effects on the environment

Criteria Pollutants

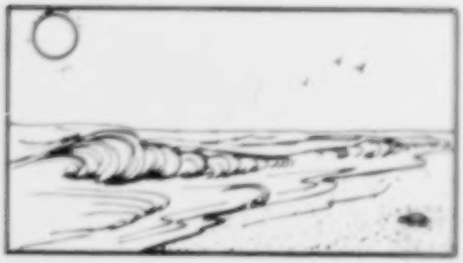
Pollutant	Symbol	form	type
Carbon monoxide	CO	gaseous	primary
Sulfur oxides	SO_X	gaseous	primary
Nitrogen dioxide	NO_2	gaseous	primary & secondary
Hydrocarbons*	HC	gaseous	primary
Ozone	O_3	gaseous	secondary
Particulate matter	TSP	particulate	primary & secondary
Lead	Pb	particulate	primary

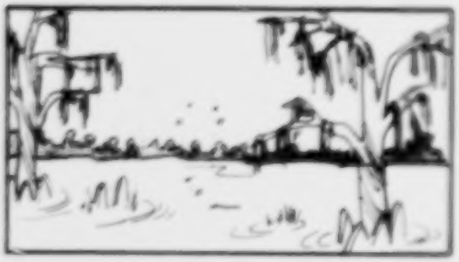
* This standard revoked January 5, 1983.

Carbon Monoxide
(CO)

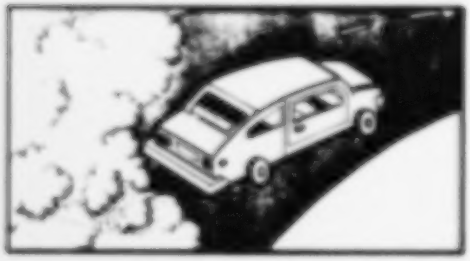
- colorless
- odorless
- tasteless

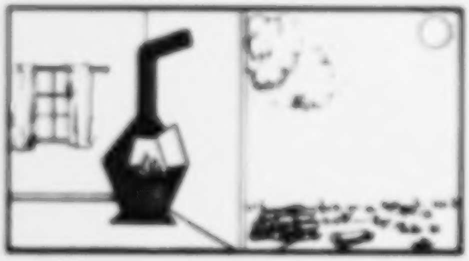
Natural Sources

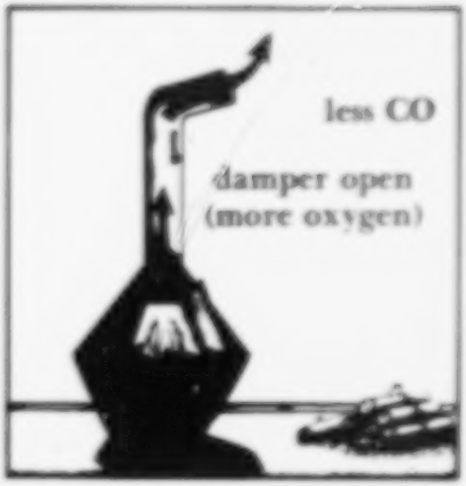


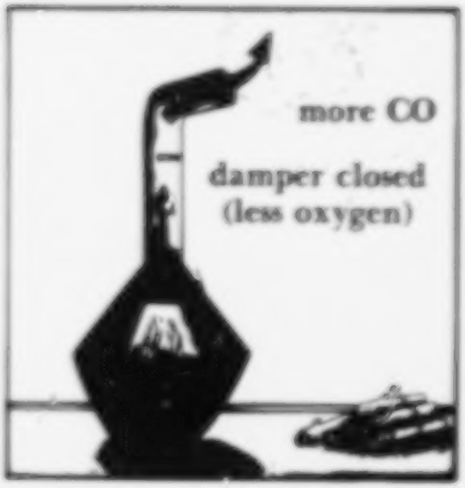


Manmade Sources






less CO
damper open
(more oxygen)

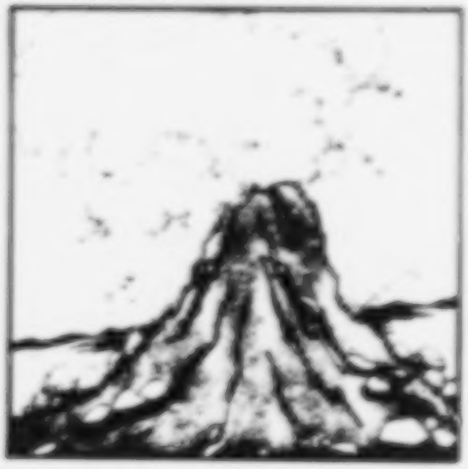

more CO
damper closed
(less oxygen)

Sulfur Oxides
(SO_X)

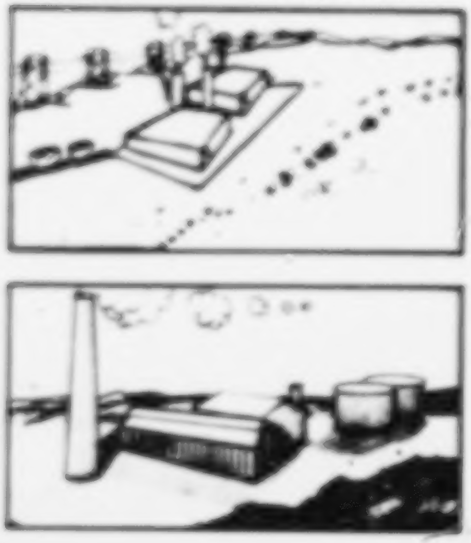
Sulfur Dioxide

- colorless
- formed when sulfur burns

Natural Sources

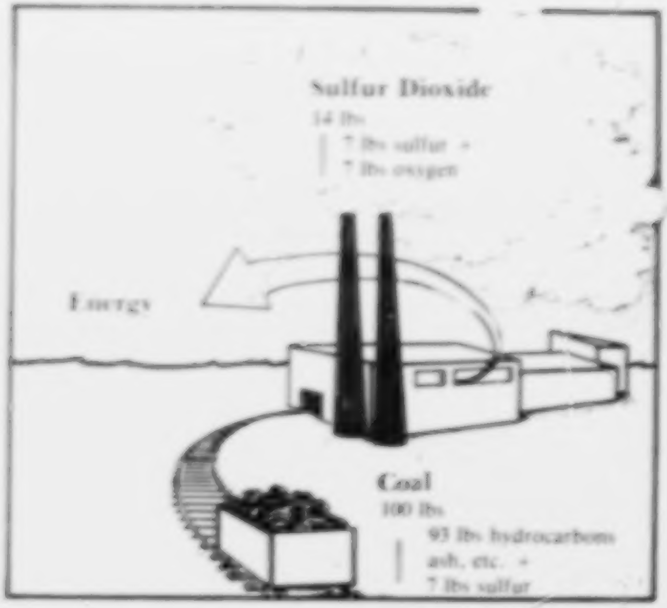


Manmade Sources

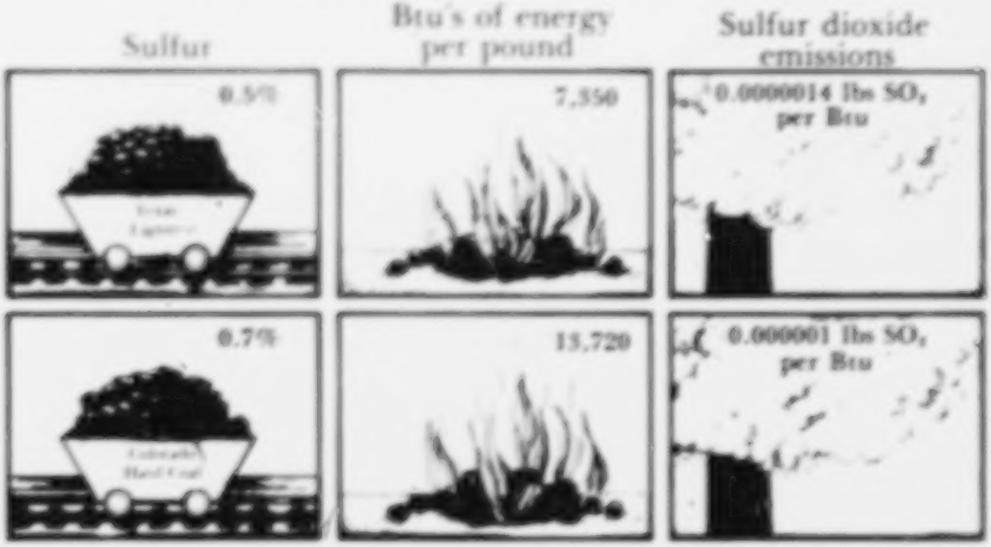


Sulfur Dioxide

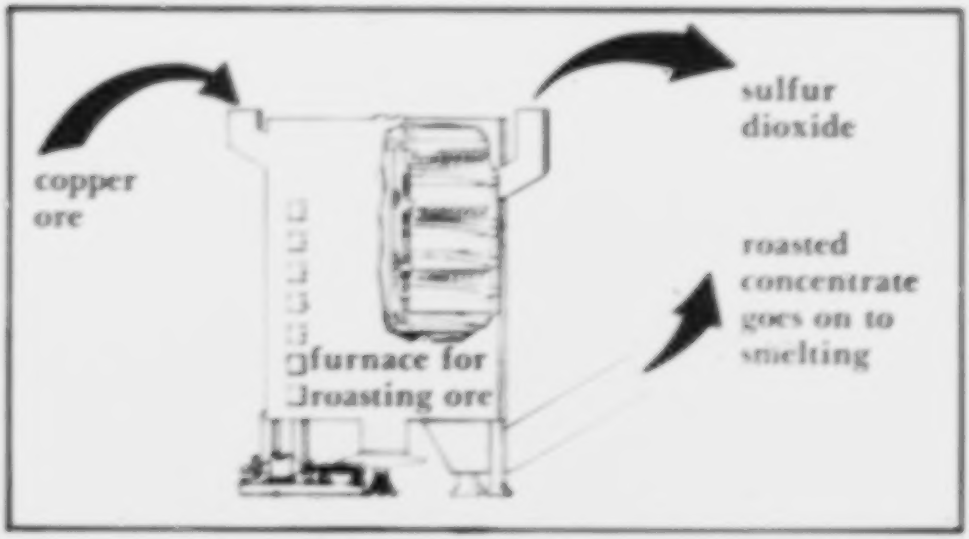
the "pass through" pollutant


Sulfur Dioxide
14 lbs
7 lbs sulfur +
7 lbs oxygen
Energy
Coal
100 lbs
93 lbs hydrocarbons
ash, etc. +
7 lbs sulfur

Amount of Energy and Sulfur Dioxide Released per Pound of Fuel

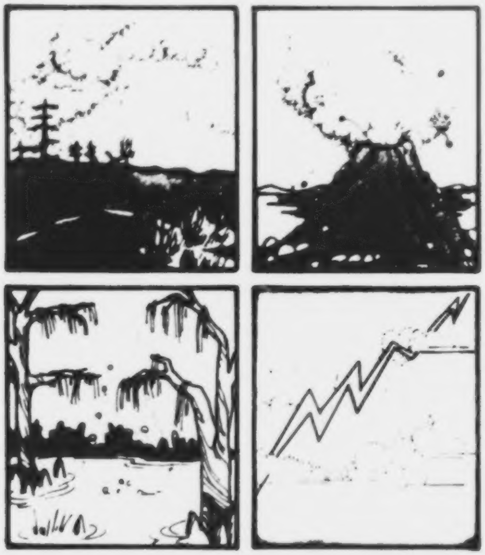

Sulfur
Btu's of energy per pound
Sulfur dioxide emissions
0.5%
Texas Lignite
7,350
0.0000014 lbs SO_2 per Btu
0.7%
Colorado Hard Coal
13,720
0.000001 lbs SO_2 per Btu

Smelting of Nonferrous Metals

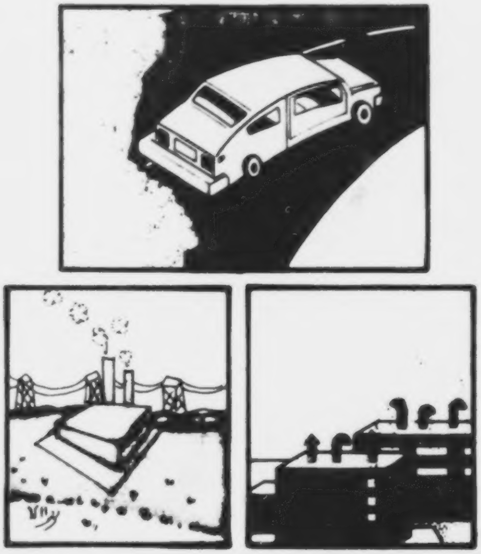

copper ore
sulfur dioxide
roasted concentrate goes on to smelting
furnace for roasting ore

Nitrogen Oxides
(NOx)

- several gases
- composed of nitrogen and oxygen
- nitrogen dioxide (NO_2) is of greatest concern—relatively more harmful than other criteria pollutants
- nitric oxide (NO) is relatively less harmful—most commonly emitted of all NOx



Natural Sources



Manmade Sources

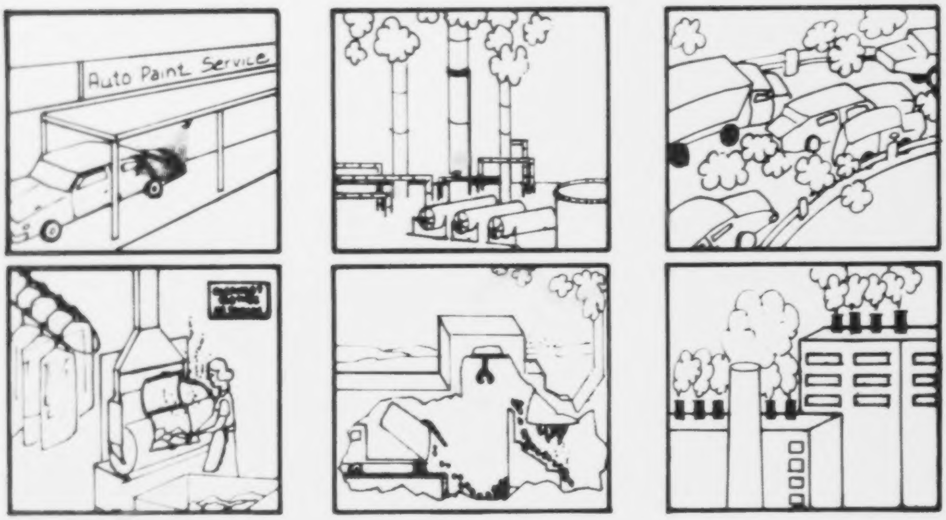
The main source of nitrogen oxides is the combustion of fossil fuels.

- Nitrogen in the fuel is oxidized to form nitric oxide and small amounts of nitrogen dioxide.
- Nitrogen in the air within the combustion chamber is also converted to nitrogen oxides, mostly nitric oxide.
- Oxidation of nitrogen from air in chamber is much slower than oxidation of nitrogen in fuel.
- Nitric oxides emitted to the air are converted to nitrogen dioxide by photochemical reactions promoted by sunlight.

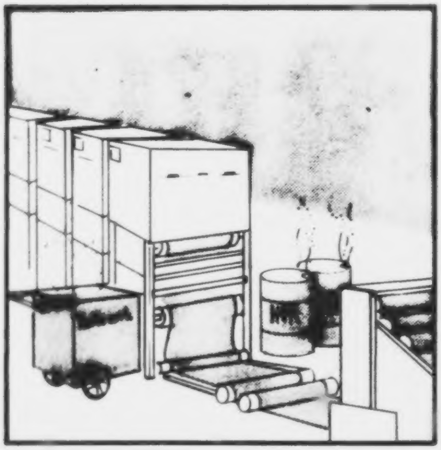
Hydrocarbons (HC)

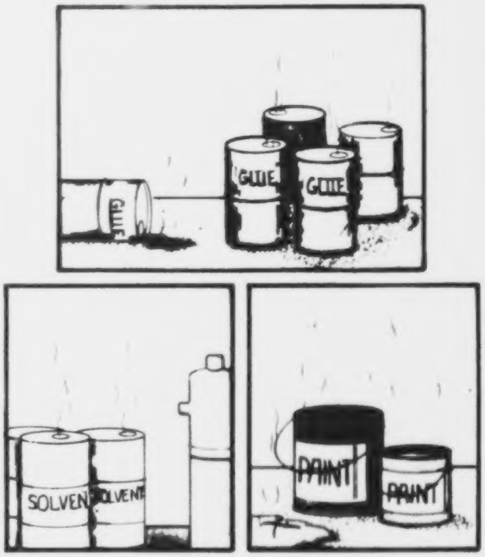
- HCs are composed of only hydrogen and carbon.
- VOC—Volatile Organic Compounds—include most volatile hydrocarbons.
- VOCs are composed of hydrogen and carbon; they may also contain elements such as oxygen, nitrogen, sulfur, chlorine, and fluorine.
- VOCs are defined to include only those compounds which take part in atmospheric photochemical processes.

Manmade Sources


Auto Paint Service

VOCs are used as solvents in many products.




GLUE
GLUE
GLUE
SOLVENT
SOLVENT
PAINT
PAINT

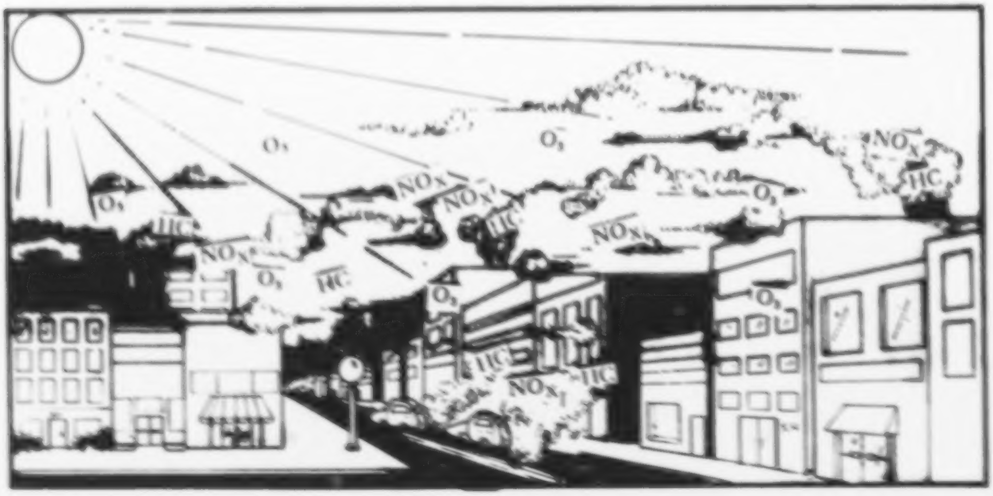
Combustion Factors Affecting VOC Emissions

- time in combustion chamber
- fuel and air mix
- turbulence in chamber
- temperature and pressure
- design of chamber

VOCs are controlled through the NAAQS because they take part in the photochemical production of ozone and other photochemical oxidants.

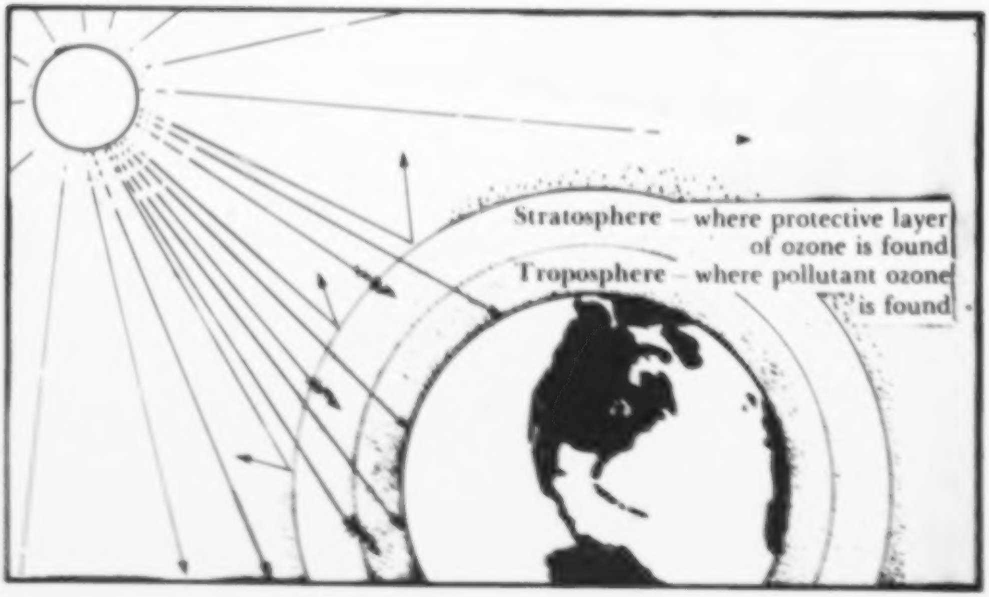
NOTE: EPA revoked the NAAQS covering hydrocarbons on January 5, 1983. However, the Agency maintained that hydrocarbons "should continue to be controlled or restricted" because they do contribute to the formation of ozone and other photochemical oxidants as stated above.

VOC Interaction with NO_X in Presence of Sunlight Forming Ozone and Other Smog

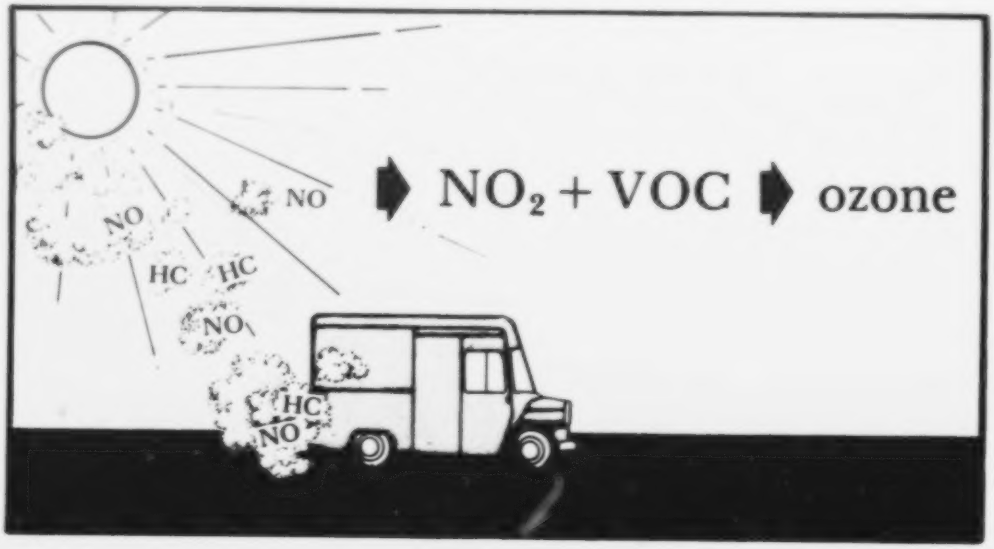


Ozone
(O_3)

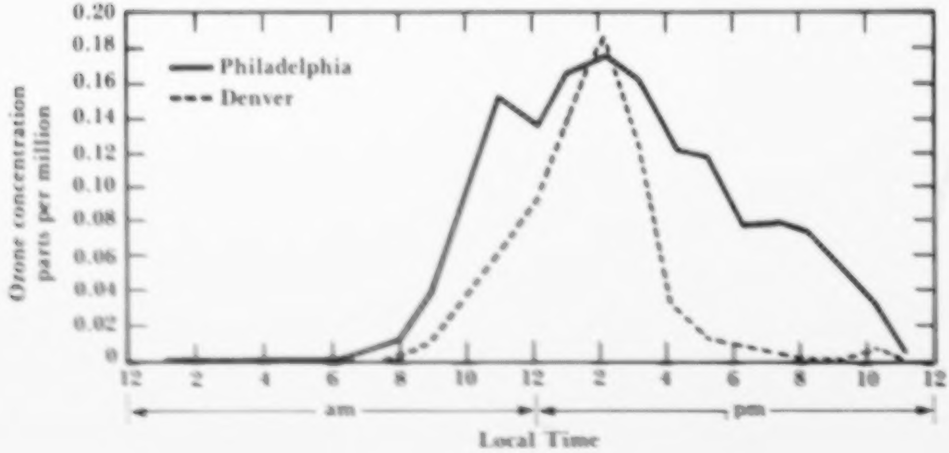
- gaseous
- secondary pollutant
- formed in our atmosphere
- the main constituent of photochemical smog


Stratosphere – where protective layer of ozone is found
Troposphere – where pollutant ozone is found

Formation of Ozone


NO
NO
HC
HC
NO
HC
NO
NO_2 + VOC
ozone

Variations in Ozone Concentration over 24 hours

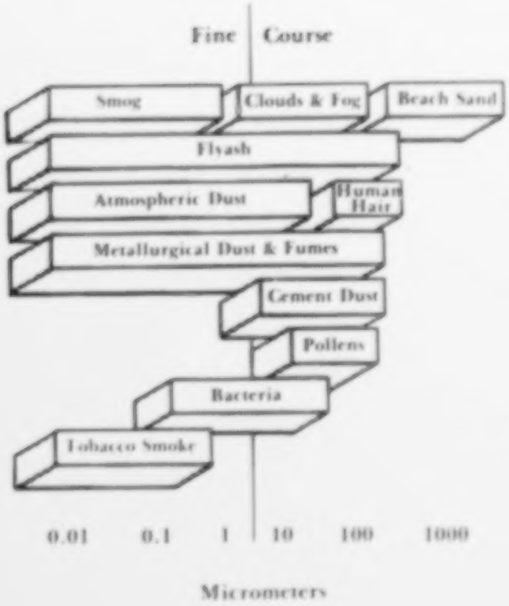


Factors Affecting Ozone Concentration

- primary pollutant concentration (HC, NO_x)
- reaction time
- reaction ratios
- intensity of sunlight
- temperature
- wind speed
- wind direction
- rainfall
- occasionally special weather conditions draw ozone-rich air from the upper atmosphere down to the earth along leading edges of cold fronts

Suspended Particulate Matter

- measured as Total Suspended Particulates (TSP)
- mostly primary pollutants, but includes some secondary pollutants
- very small pieces of liquid or solid matter



Sizes of Typical Airborne Particles Compared to Common Materials

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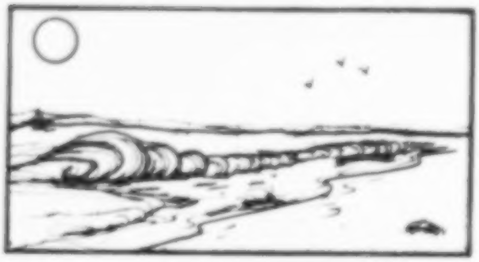
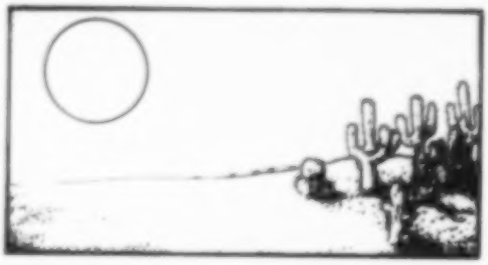
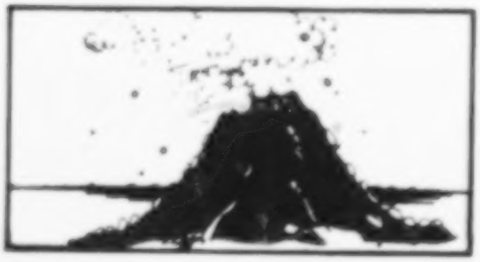
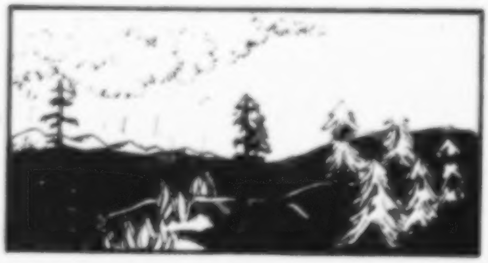
Natural Sources

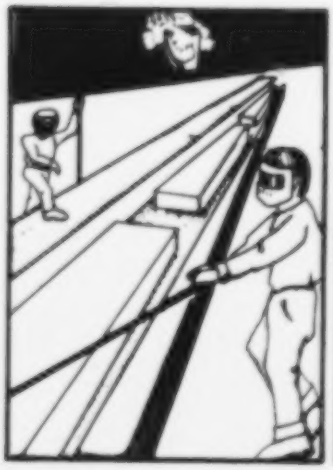


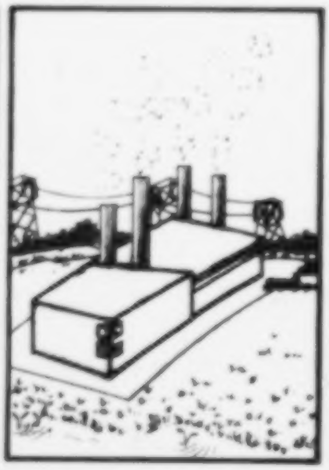


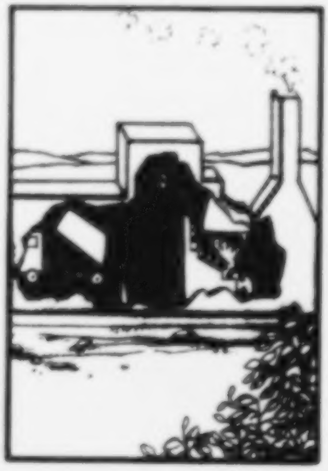




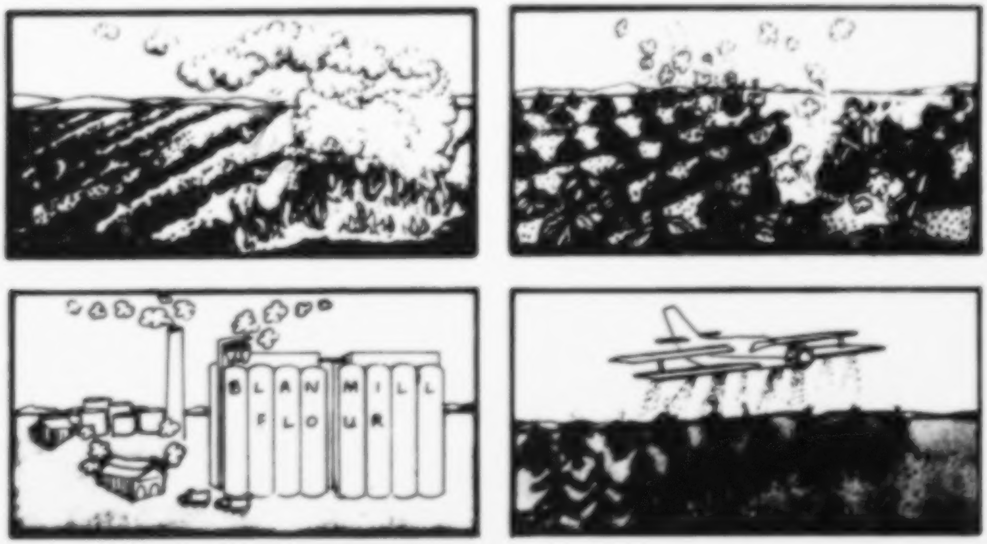
Manmade Sources

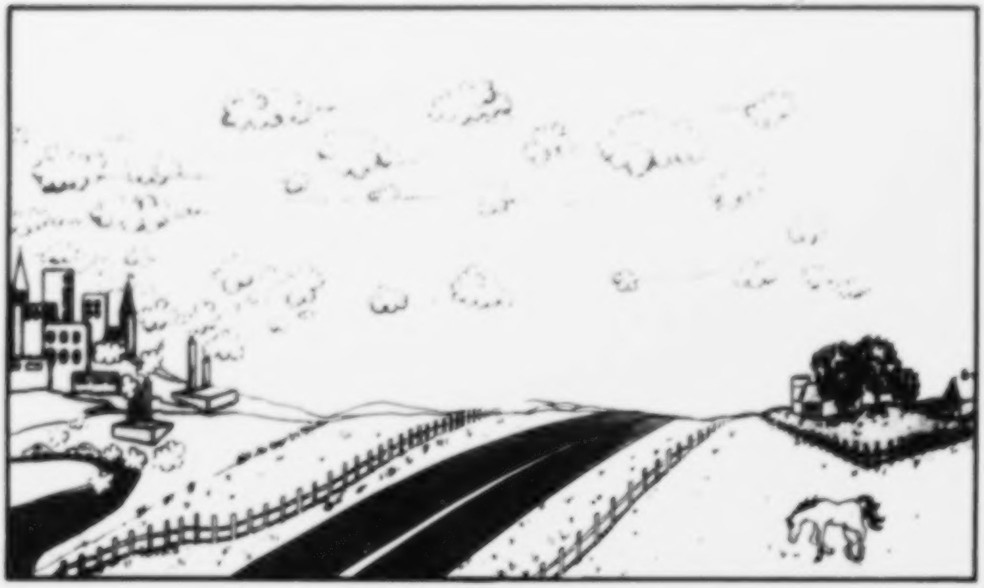






Agricultural Processes Contributing to TSP


BLAN MILL
FLOUR



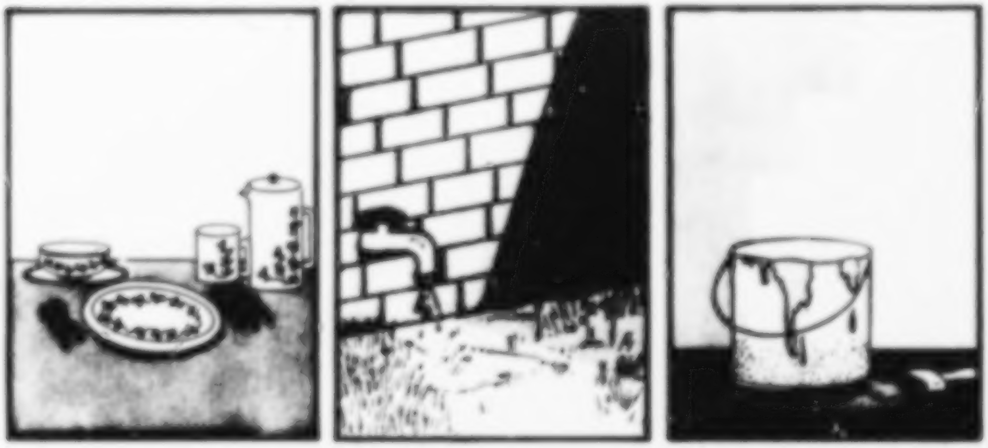
In addition to the pollution problems caused by the suspended particles themselves, these particles combine with other pollutants to form secondary—and sometimes more harmful—pollutants.

Lead (Pb)

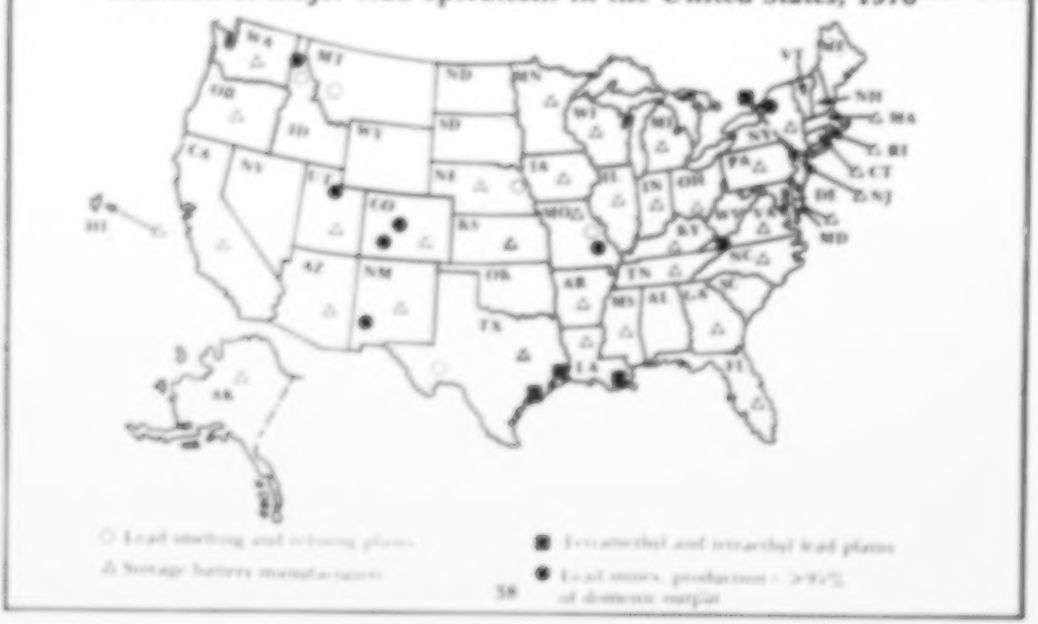
- grey metal
- fairly abundant
- derived from ore-bearing minerals
- can be easily formed, molded, and worked
- withstands weathering and chemical erosion

- Most of the lead used in U.S. is mined in Missouri.
- Lead consumption in U.S. in 1976 was about 1,350,000 metric tons.
- Each year about 600,000 metric tons of lead are used in storage batteries.
- About 200,000 metric tons of lead are used in the manufacture of gasoline additives.

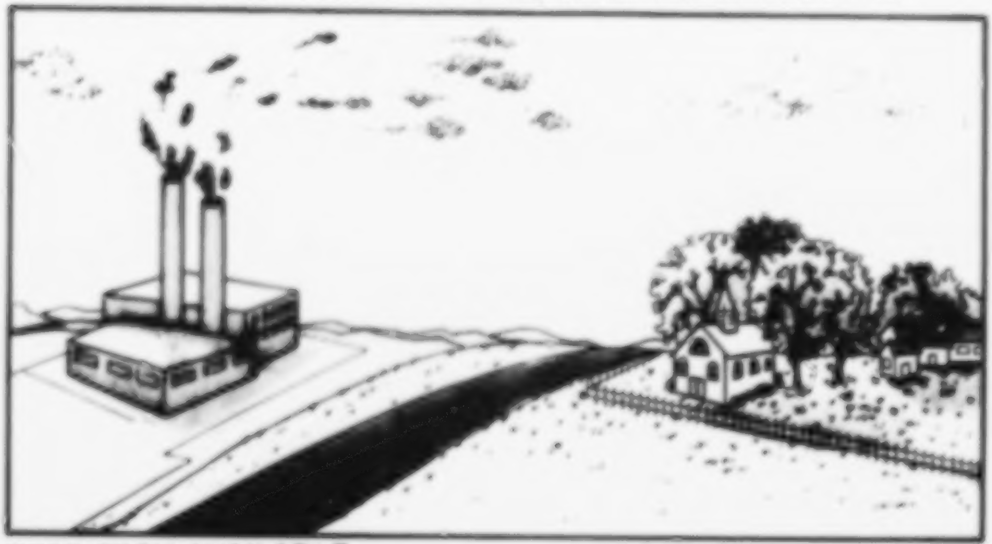
Because of its physical properties, lead has been used for…



Location of major lead operations in the United States, 1976


WA
MT
OR
ID
WY
ND
SD
MN
WI
MI
NY
VT
ME
NH
MA
RI
CT
NJ
DE
MD
PA
OH
IN
IL
IA
NE
CA
NV
UT
CO
KS
MO
KY
WV
VA
NC
TN
AR
OK
AZ
NM
TX
LA
MS
AL
GA
SC
FL
HI
AK
○ Lead smelting and refining plants
△ Storage battery manufacturers
■ Tetramethyl and tetraethyl lead plants
● Lead mines, production > 90% of domestic output
38

Distribution of Lead Emissions



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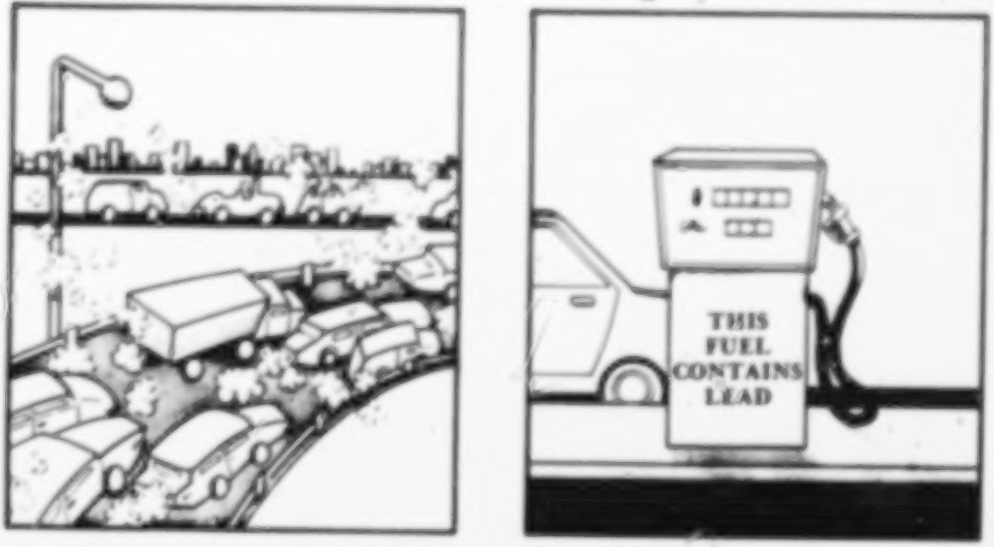
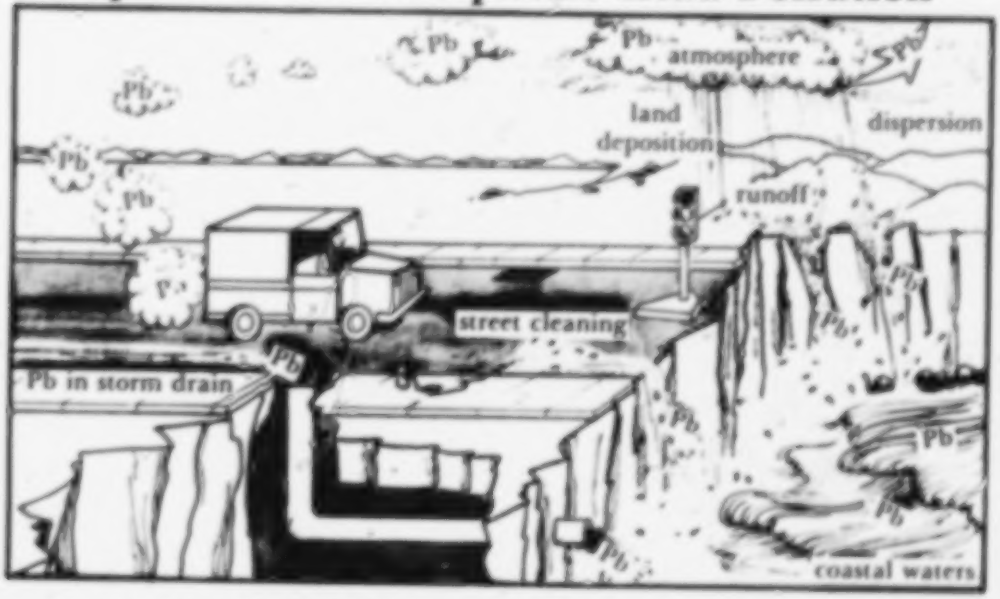
Major Source of Atmospheric Lead


THIS
FUEL
CONTAINS
LEAD

Deposition of Atmospheric Lead Pollution


Pb
Pb
Pb
atmosphere
Pb
land
deposition
dispersion
Pb
Pb
runoff
P
street cleaning
Pb
Pb in storm drain
Pb
Pb
Pb
Pb
Pb
Pb
coastal waters

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Hazardous Pollutants

- Pollutants that may cause or contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness
- Usually cause only localized problems
- Controlled with emissions standards rather than by limitations on the concentrations allowable in the ambient air

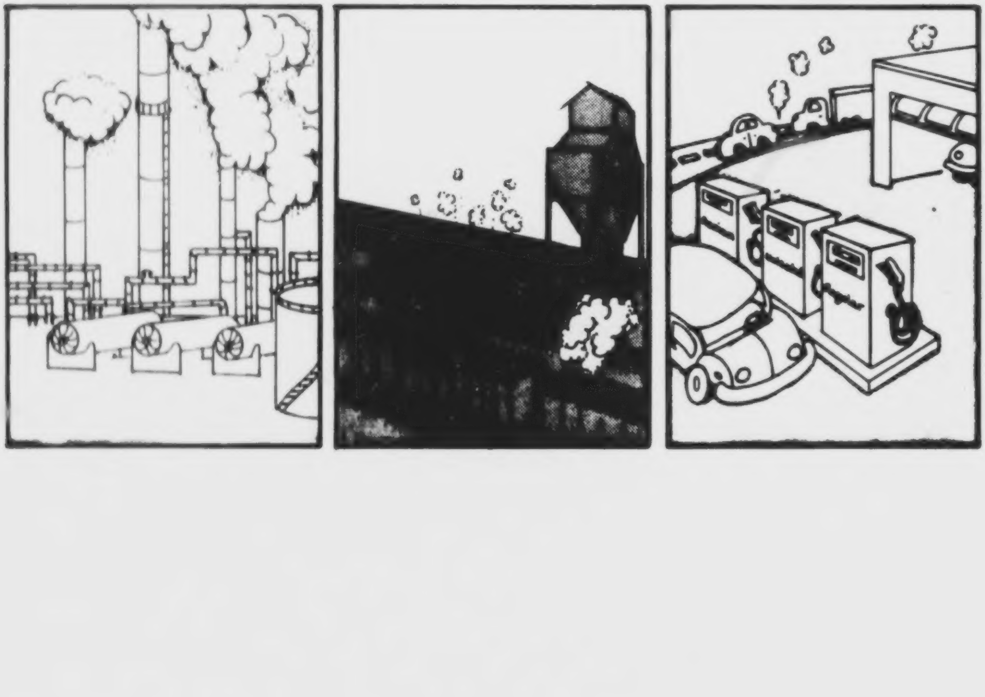
Hazardous Pollutants

Asbestos
Benzene
Vinyl Chloride
Beryllium
Mercury
Arsenic

Sources of Asbestos

- mining, milling, and spraying of asbestos
- manufacturing of asbestos-cement products, paper, plastics, gaskets, packings, roofing felts, and insulation

Sources of Benzene



Sources of Beryllium

- beryllium extraction plants
- machine shops working with beryllium-containing metals
- foundries handling beryllium or beryllium-containing alloys
- ceramic plants using beryllium
- rocket propellants containing beryllium
- incinerators burning waste that contains beryllium

Sources of Mercury

- mercury-ore processing plants
- mercury battery manufacturing plants
- plants which dispose of sewage treatment plant sludge by drying or burning

Sources of Vinyl Chloride

- Production of polyvinyl chloride
- General public exposure may result from use in
  - aerosol containers
  - food wrapping and containers
  - plumbing pipes
  - other plastic products

Other Pollutants Under Study for Possible Designation as Hazardous Air Pollutants

Manganese
Cadmium
Nickel
Polycyclic organic matter (coke oven emissions)
Ethylene dichloride
Formaldehyde
Vinylidene chloride
Epichlorohydrin
Ethylene oxide
Acrylonitrile

Lesson I
Questions

1. What are the two basic physical forms of air pollution?

Match the criteria pollutant listed below with its appropriate description

2. carbon monoxide
3. sulfur dioxide
4. nitrogen dioxide
5. hydrocarbons*
6. ozone
7. suspended particulate matter
8. lead

a. colorless gas—one major source is fossil-fuel combustion—"pass-through" pollutant

b. ORGANIC MOLECULES CONTAINING VARIOUS COMBINATIONS OF CARBON AND HYDROGEN ATOMS

c. grey metal—one major source is combustion of gasoline

d. very small pieces of liquid or solid matter

e. colorless, odorless, and tasteless gas—one major source is the automobile engine

f. secondary pollutant—forms when hydrocarbons and nitrogen oxides react in the presence of sunlight

g. results from the oxidation of nitric oxide in the air and is considered to be more hazardous than NO

* revoked as a criteria pollutant on January 5, 1983

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Answers

1. gaseous and particulate
2. e
3. a
4. g
5. b
6. f
7. d
8. c

Lesson II: Pollutant Sources

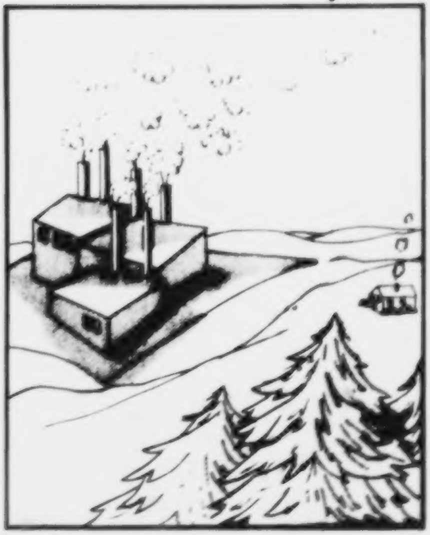
Objectives

1. List and describe five mutually exclusive air pollutant source categories.
2. Identify an example of a source in each of the five major source categories.
3. Given examples of sources, distinguish between point sources and area sources.
4. State a major manmade source for each criteria pollutant.

Source classifications may be based upon

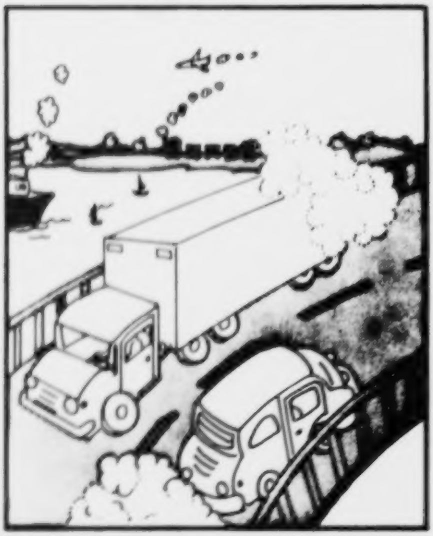
- whether the source is
  - stationary or mobile
  - combustion or noncombustion
  - area or point
- the way that the source generates emissions.

Stationary

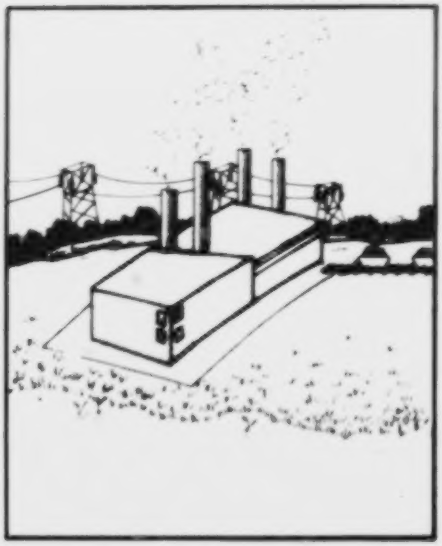


or

Mobile

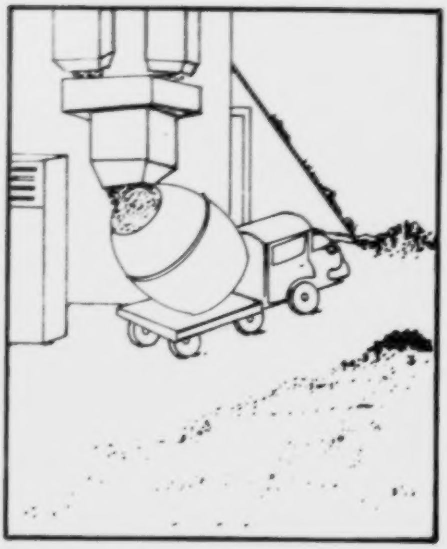


Combustion

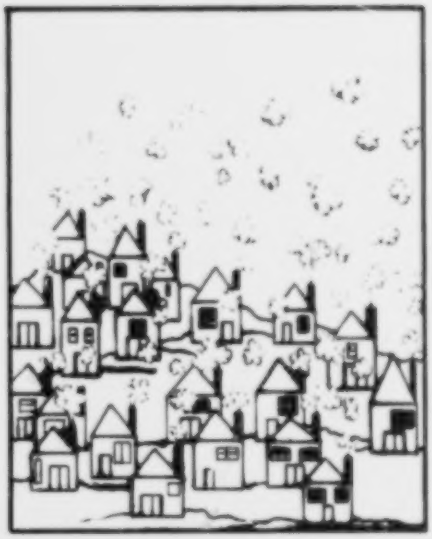


or

Noncombustion

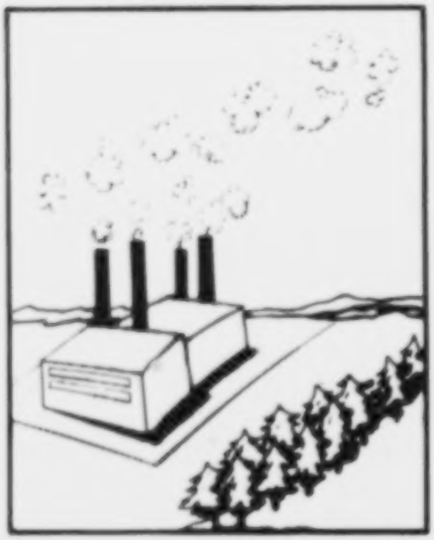


Area

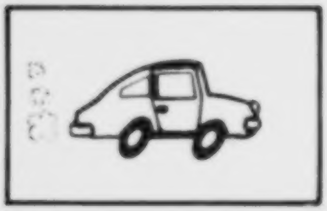


or

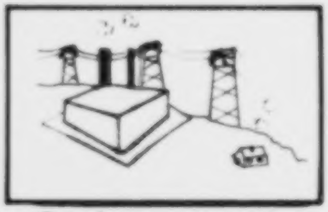
Point



Emission Generation Categories

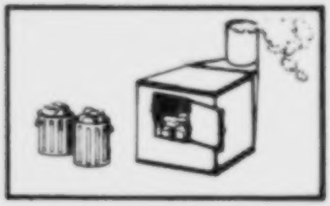


Transportation



Stationary source fuel combustion

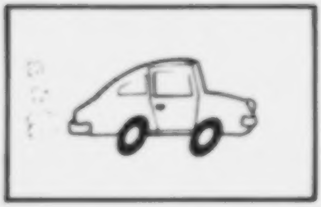
Industrial processes



Solid waste disposal

Miscellaneous

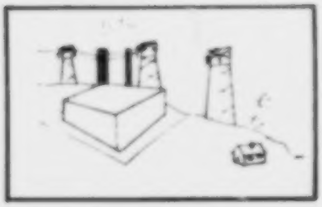
Transportation Sources



Most emissions produced in the combustion process that powers their motion. Evaporation of gasoline is also an important source of volatile organic emissions.

- biggest mobile emission producers are the gasoline- and diesel-fueled internal combustion engines used in motor vehicles
- other sources include planes, ships, trains, lawnmowers, farm tractors, and construction machinery

Stationary Combustion Sources

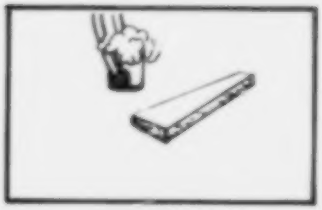


Produce energy but no other products. Emissions result from fuel combustion.

- fixed energy generating sources ranging in size from home heating furnaces to major power plants.

- sources include commercial, institutional, industrial, and steam-electric power plants.

- fuels used include coal, oil, natural gas, and wood. Other fuels such as liquified natural gas, propane, process gas, etc. may also be used.

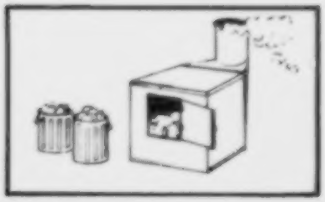


Industrial Processes

Emit pollutants in the course of manufacturing products

- major sources include chemical processing, food and agricultural industries, metallurgical and mineral product factories, petroleum refining, petrochemical plants, petroleum storage, and wood processing industries
- smaller (area) sources include painting, dry-cleaning, and degreasing operations

Solid Waste Disposal



Facilities that dispose of unwanted products and by-products. Emissions result from the disposal process, usually burning.

- Most important emission sources in this category are refuse incineration and open burning.

Disposal operations range in size from small-scale burning of home trash to large central municipal incinerators.

Miscellaneous

Types of sources that do not fit into the other four categories

- the distribution of these sources is scattered and variable
- sources include house fires, forest fires, agricultural burning, asphalt road paving, and coal mining

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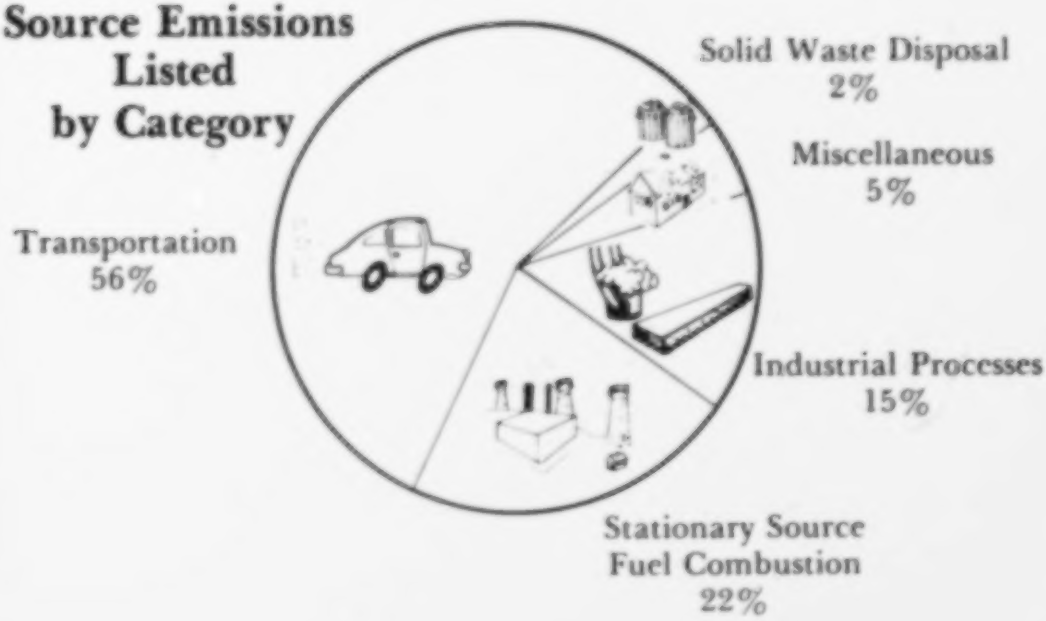
Pollutants and Sources

	Transportation	Stationary source fuel combustion	Industrial processes	Solid waste disposal	Miscellaneous
CO	gasoline powered motor vehicles	improperly adjusted boilers	process losses when CO water gas burning not practical	on site incinerators	forest burn off house fires coal refuse fires
TSP	gasoline vehicles tire wear aircraft diesel vehicles ship boiler emissions	power plants space heating commercial boilers	handling, processing and storing of rock, sand, and gravel metallurgical processes cement plants	incinerators	forest burn off house fires agricultural burning fugitive dust
HC	gasoline powered motor vehicles gasoline distribution and marketing	fossil fuel burning for power plants, space heating, and commercial boilers	petroleum refineries chemical mfg degreasing	organic chemical waste disposal	oil and gas production dry cleaning
NO_x	gasoline powered motor vehicles diesel powered vehicles	fossil fuel burning for power plants, space heating, and commercial boilers	explosives mfg rocket fuel mfg nitric acid mfg	incineration of plastics and other high temperature disposal of chemical wastes	grass fires forest burn off
SO_x	fuel additives gasoline and diesel powered vehicles	power plants space heating commercial boilers	petroleum refineries smelters sulfuric acid plants coke ovens pulp and paper mills	high temperature disposal of chemical wastes incinerators	burning of coal refuse piles
Lead	leaded fuels used in motor vehicles	burning of waste oils containing lead	smelters battery mfg gasoline additive mfg lead reclaiming operation lead glass mfg	incineration of old battery cases incineration of wood products with painted surfaces	weathering of painted surfaces



Lesson II

Questions

1. List five mutually exclusive air pollutant source categories.
2. Fill in the blank. ____________ sources are small multiple sources that together can adversely affect air quality in an area.
3. For each source listed below, name the source category (from question 1) to which it belongs.

a. power plant	d. fugitive dust
b. municipal incinerator	e. chemical processing plant
c. automobile	*Answers are on the next page.*

Lesson II

Answers

1. transportation
   stationary source fuel combustion
   industrial processes
   solid waste disposal
   miscellaneous
2. area
3. a. stationary source fuel combustion
   b. solid waste disposal
   c. transportation
   d. miscellaneous
   e. industrial process

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Unit Test

1. What are the two basic physical forms of air pollution?
2. Which of the following is not a criteria pollutant?
   a. sulfur dioxide
   b. asbestos
   c. lead
   d. ozone
   e. suspended particulate matter
   f. hydrocarbons
   g. nitrogen dioxide
   h. carbon monoxide
3. True or false? Hazardous pollutants, unlike criteria pollutants, are controlled with emissions standards rather than by ambient air quality standards which limit the concentration of a pollutant allowable in the ambient air.
4. The most widely used system of classifying pollution sources divides them into five mutually exclusive categories based on the way that the emissions are generated in the source. These include which of the following?
   a. solid waste disposal
   b. industrial processes
   c. transportation
   d. aerospace operations
   e. stationary source fuel combustion
   f. smelting processes
   g. liquid waste disposal
   h. miscellaneous sources
5. Is a large petroleum refinery with great quantities of pollutant emissions and many exhaust stacks an area source or a point source?

Answers

1. particulate
   gaseous
2. b. asbestos and f. hydrocarbons.
3. True
4. a, b, c, e, and h
5. point source

PART II

Effects of Air Pollution

Lesson I: Why Study Effects

Objectives

1. Define the term "effect" as it pertains to air pollution.
2. List four reasons why we should be concerned about and study about air pollution effects.
3. Describe what is meant by the term "ambient air."
4. Identify the type of pollutants that are discussed in this module.
5. Identify what is meant by the terms "primary standards" and "secondary standards" as they pertain to air pollution control.
6. Identify the seven criteria air pollutants. *

NOTE: As of January 5, 1983 EPA revoked the hydrocarbon standard which reduces the number to six.

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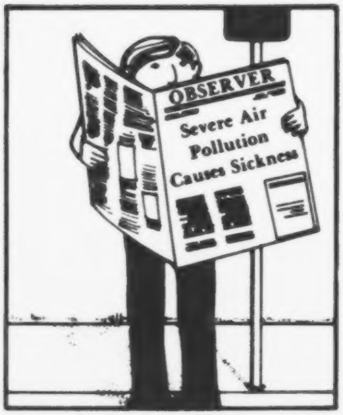
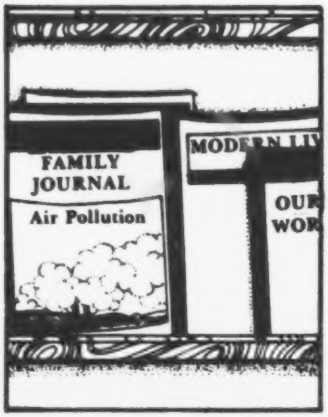
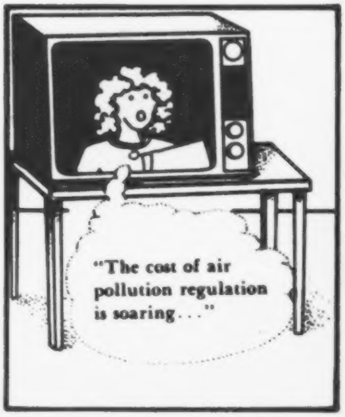
What We Hear About

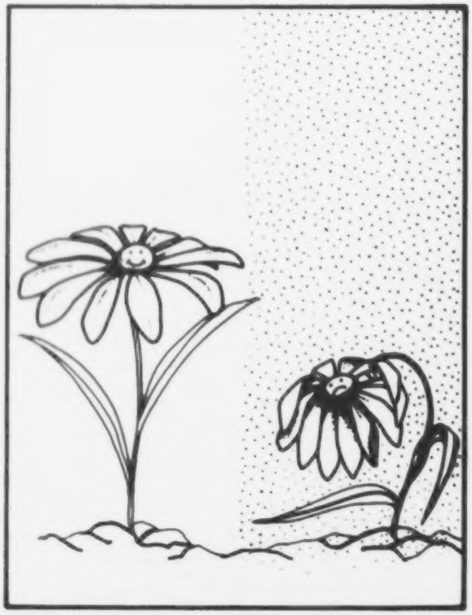

OBSERVER
Severe Air Pollution Causes Sickness


FAMILY JOURNAL
Air Pollution
MODERN LIV
OUR WOR

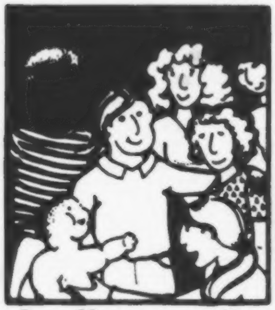

"The cost of air pollution regulation is soaring..."

Effect

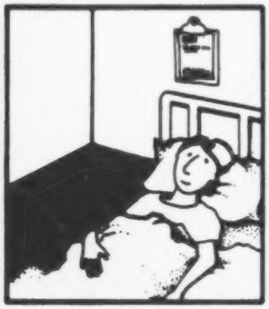
A measureable or perceivable detrimental change resulting from an air pollutant. The pollutant may affect humans, plants, animals, microbes, or other living matter—or may affect non-living materials such as paints, metals, fabrics, etc., or may cause a decrease in visibility. The things receiving pollution are called "receptors."



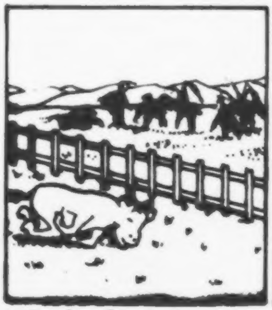
Why worry about air pollution?



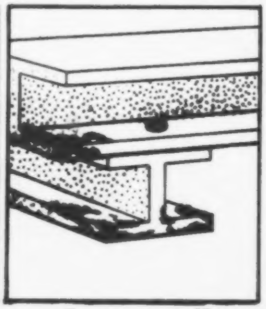
It affects us all.



It can cause sickness, injury, and death.

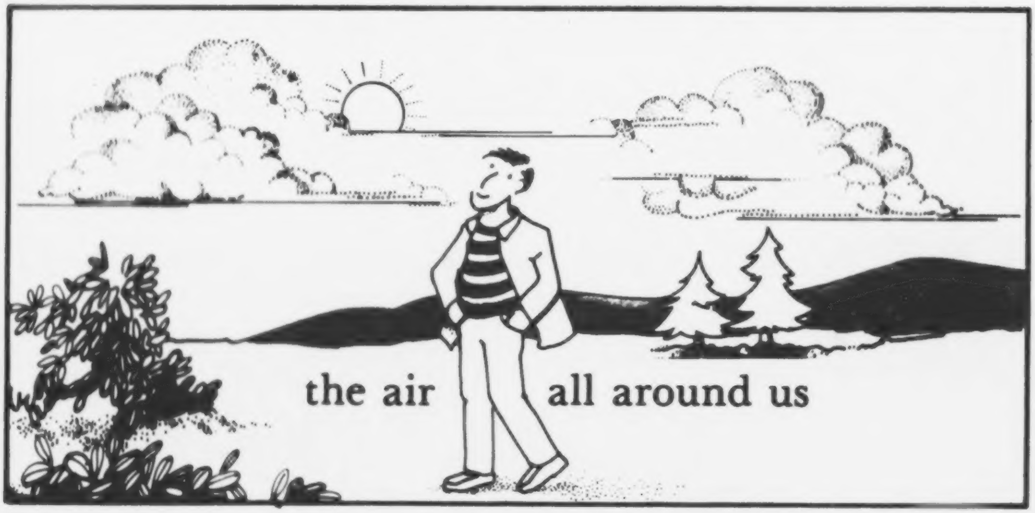


It is destructive to crops and detrimental to farm animals.

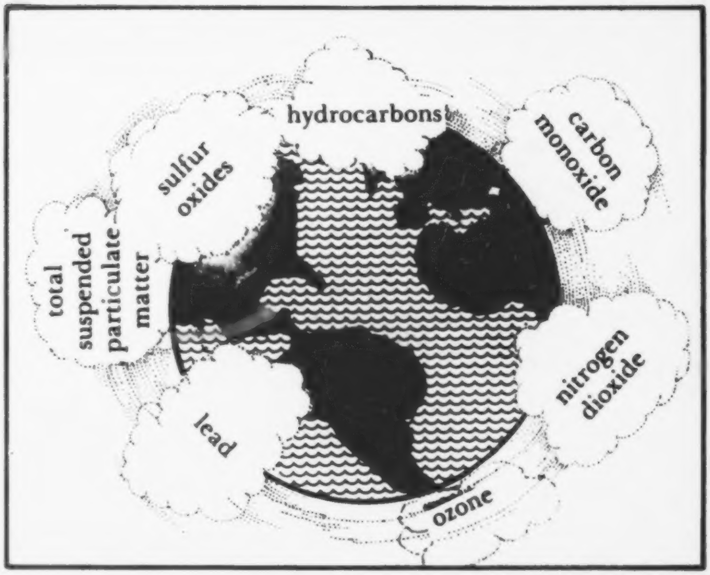


It can soil and corrode materials.

Ambient Air...



The Seven* Criteria Air Pollutants


hydrocarbons
carbon monoxide
sulfur oxides
total suspended particulate matter
nitrogen dioxide
lead
ozone

* Six, since the revoking of the hydrocarbon standard

For Criteria Pollutants

Primary Standards
Set to protect human health

Secondary Standards
Set to protect public welfare

The evidence upon which air pollution standards are based is gathered from:

- case studies
- laboratory research
- general field studies
- other sources

Lesson I
Questions

1. State in your own words what is meant by the term "effect" as it pertains to air pollution.
2. List four reasons why we should be concerned about and study about air pollution effects?
3. Choose the phrase that *best* completes the sentence. Ambient air is
   a. the air in the top part of a belching smoke stack.
   b. the air inside a factory.
   c. the air all around us.
   d. the air contained in buildings.
4. This unit, entitled "The Effects of Air Pollution," is concerned with which of the following type(s) of pollutants?
   a. all air pollutants
   b. uncontrolled pollutants
   c. criteria pollutants
   d. none of the above

5. Choose the term that best completes the sentence. Primary standards are set to protect
   a. human health.
   b. property.
   c. cattle and other livestock.
   d. buildings.
6. Which of the following is *not* a criteria pollutant?
   a. ozone
   b. arsenic
   c. carbon monoxide
   d. sulfur dioxide
   e. lead
   f. nitrogen dioxide
   g. hydrocarbons
   h. total suspended particulate matter

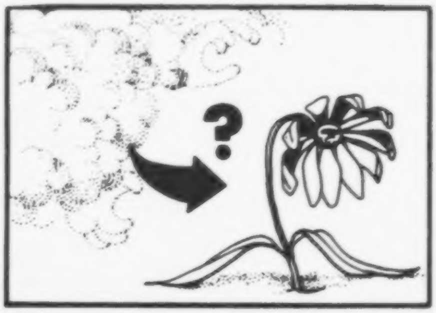
Lesson I
Answers

1. An effect is a measureable or perceivable detrimental change resulting from an air pollutant. The pollutant may affect humans, plants, animals, microbes, and other living or non-living matter.
2. Any four of the following:
   It affects us all.
   It is destructive to crops and detrimental to farm animals.
   It can soil and corrode materials.
   It decreases visibility.
   It causes acid rain.
   It causes odors and other nuisances.
3. c. the air all around us
4. c. criteria pollutants
5. a. human health
6. b. arsenic and g. hydrocarbons.

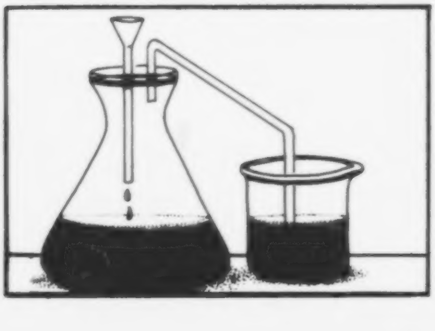
Lesson II: How Effects Are Studied

Objectives

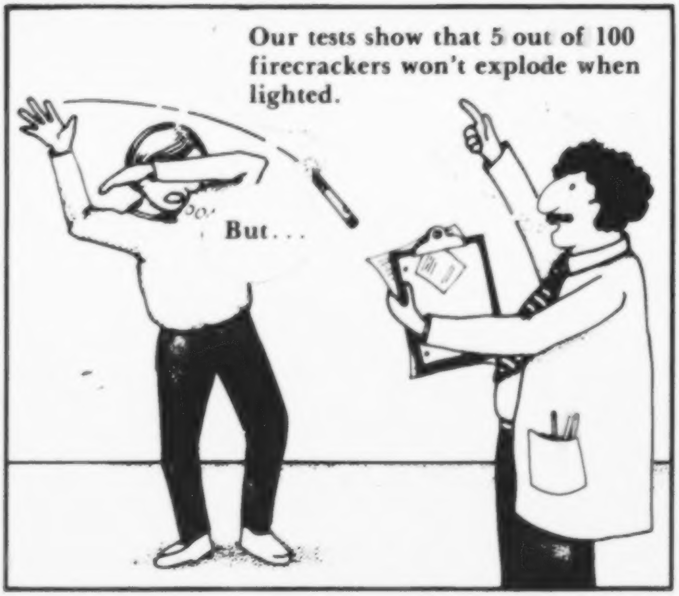
1. Identify the kind of relationships that scientists are investigating when they study air pollution.
2. Name three major types of air pollution studies.
3. Describe what is meant by the term "synergistic effect" as it pertains to air pollution.



Scientists are looking for **causal relationships,** that is, evidence which proves that exposure to a specific pollutant causes an identifiable adverse effect. However, such precise evidence about the complex polluted atmosphere is **virtually impossible to obtain.**



The best that can be done is to **use scientific methods and statistical tests** to **reduce the uncertainty about** the observed **relationship** between a specific pollution situation and an identifiable effect.


Our tests show that 5 out of 100 firecrackers won't explode when lighted.
But...

Does an hypothesis have to be demonstrated without exception to be believable?

Case Studies

Characteristics

- usually conducted after occupational or accidental exposure resulting in adverse effects
- result in a tracing backward from observed effects to probable causes
- are "after-the-fact" studies

Advantages

- are "real life" situations
- effects of human exposure to high concentrations can be studied after the fact
- long-term effects can be monitored

Disadvantages

- generally small groups are involved
- some variables unaccounted for
- studies must be interpreted in terms of other studies
- no control over timing

Laboratory Research

Characteristics
- designed to measure the effect of exposure to a specific concentration of a pollutant

Advantages
- can more accurately investigate causal relationships because variables are more controlled and some variables can be eliminated
- can repeat the experiment
- have control over timing
- can select subjects, concentrations, exposure times, etc.

Disadvantages
- in health effects area, are severe limitations on experiments with humans to determine cause-and-effect relationships
- when working with plants and animals, can only test one cause-and-effect relationship at a time
- using data to predict effects in "real life" can't be done precisely
- usually work with only small groups — cannot guarantee that they are representative and that extrapolated results are totally accurate

General Field Studies

Characteristics
- use statistical methods to determine impact on general population
- trace possible causes of known effects

Advantages
- are looking at real-life, actually occurring situations
- can measure effects and concentrations rather accurately while they are occurring
- subjects constitute a more representative sample of the population as a whole
- can select specific subjects from the population, if desired

Disadvantages
- not repeatable
- don't necessarily know prior exposure history of subjects
- often have no control over timing and other variables
- estimates of effects on total population must be made only on a statistical basis

Research Methods Used in Studying the Effects of Air Pollution

Type	Receptors	Exposure Conditions	Advantages/Disadvantages
Case Studies	Humans vegetation & materials	Occupational and or accidental	Real life situation Effects of human exposure to high concentrations can be studied after the fact Long term effects can be monitored Usually involves small groups Some variables unaccounted for Study interpreted in terms of other studies No control over timing
Laboratory Research	Humans animals plants & materials	Carefully controlled exposure subjects & other important variables	Can more accurately investigate causal relationships since variables more controlled and some can be eliminated Can repeat experiment Control over timing Can select subjects, concentrations, exposure times, etc Severe limitations on experiments with humans to determine cause and effect relationships With plants and animals, can only test one cause and effect relationship at a time Using data to predict effects in "real life" can't be done precisely Usually work with only small groups cannot assume representativeness or accuracy of extrapolated results
General Field Studies	Humans animals plants & materials	Ambient conditions	Real life, actually occurring situations Can measure effects and concentrations accurately while they are occurring Subjects more representative of population as a whole Can select specific subjects from population Not repeatable Don't necessarily know prior exposure history of subjects No control over timing and other variables Estimates of effects on total population must be made only on a statistical basis

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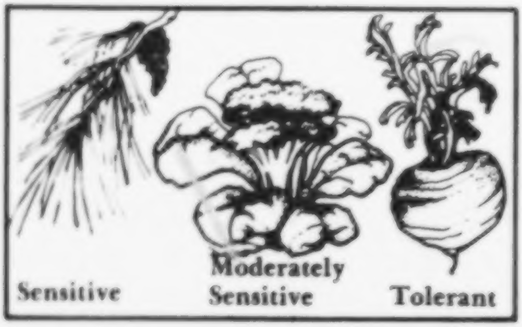
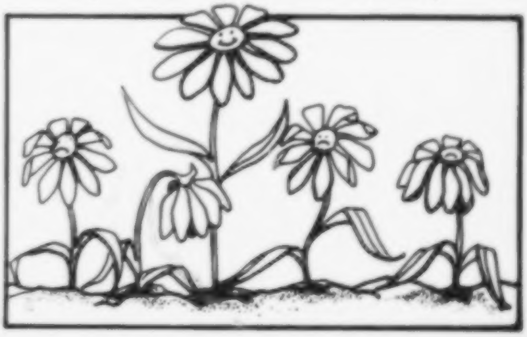
Different species may have different sensitivities to a specific pollutant.

Sensitivity to ozone . . .



The impact of a pollutant upon a population in general can be predicted, but the reaction of any individual within the population cannot be predicted with certainty.

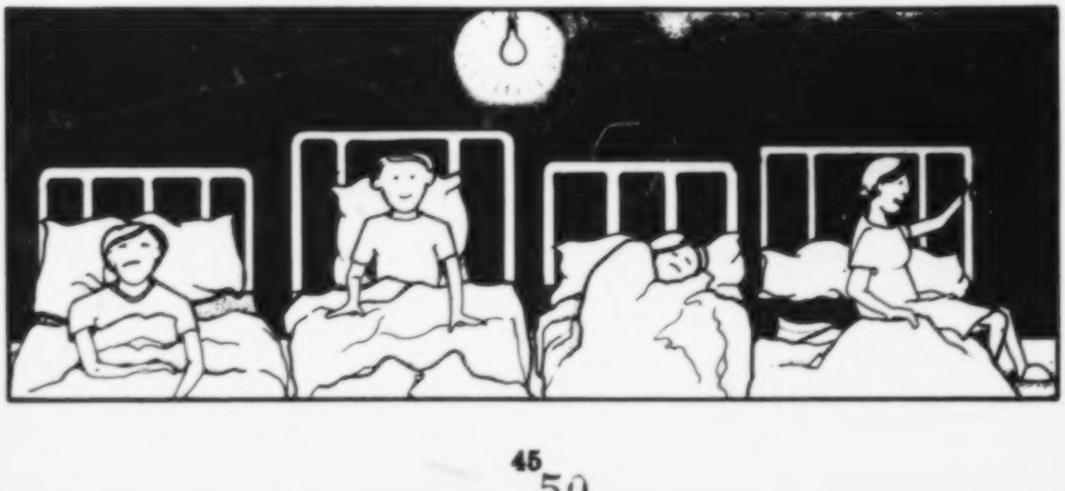


Individual differences in humans are significant in terms of reaction to a pollutant.

Factors affecting reaction include

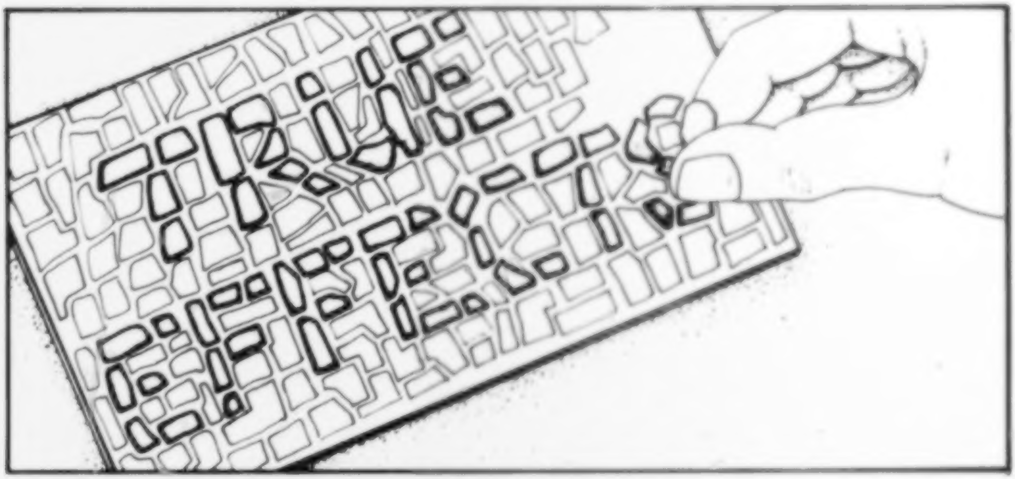
- genetic make-up
- health
- history of exposure
- preconditioning
- function-pollutant reaction systems

There are individual and species differences in the rate of recovery from a pollutant exposure.



Types of Effects

synergistic-	combined effect of pollutants is worse than the simple sum of effects of individual pollutants
additive-	combined effect of pollutants is the same as sum of effects of individual pollutants
potentiator-	toxic substance made worse by presence of non-toxic substance
antagonistic-	effect of toxic substance lessened by presence of non-toxic substance



Each bit of data must be viewed in perspective with all of the other data.

Lesson II
Questions

1. Choose the term that best completes the sentence. A scientist studying the effects of air pollution is most probably trying to investigate a(n) __________ relationship.
   a. inverse
   b. inaccurate
   c. angular
   d. causal
2. List the three major types of air pollution studies.
3. In the field of air pollution, what is meant by a "synergistic effect"?

Lesson II
Answers

1. **d. causal**
2. **case studies**
   laboratory research
   general field studies
3. **When the combined effect of pollutants is *worse* than the simple sum of the effects of the individual pollutants.**

Lesson III: Suspended Particulate Matter

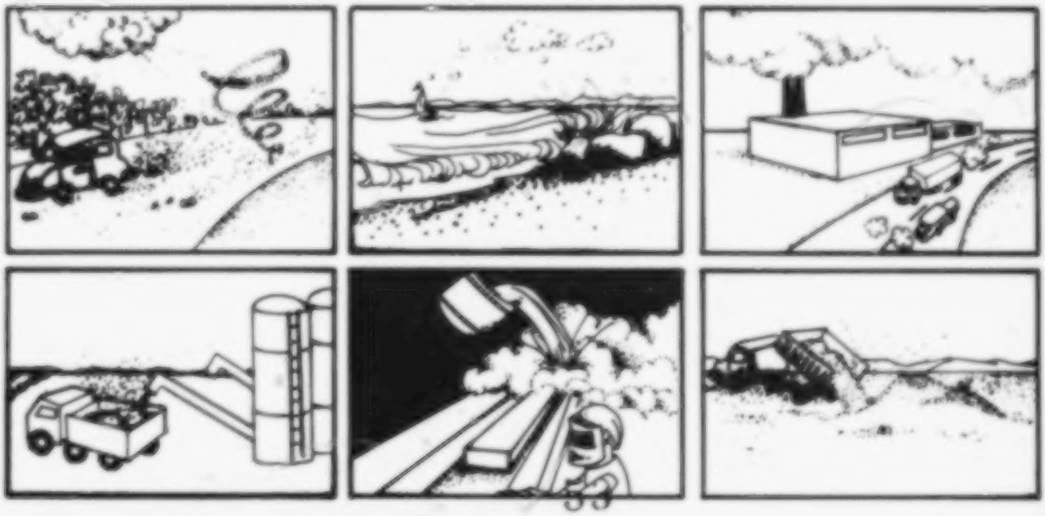
Objectives

1. Name three physical characteristics of suspended particulate matter.
2. State the two major factors that may modify the toxicity of suspended particulate matter.
3. Identify the three regions of the human respiratory system and their particle removal systems.
4. Define the terms "alveolus" and "cilia."
5. Describe the three ways that suspended particulate matter can affect visible light and identify a major economic effect of suspended particulate matter.

Suspended Particulate Matter

- very small particles
- solid or liquid
- float in air/settle very slowly

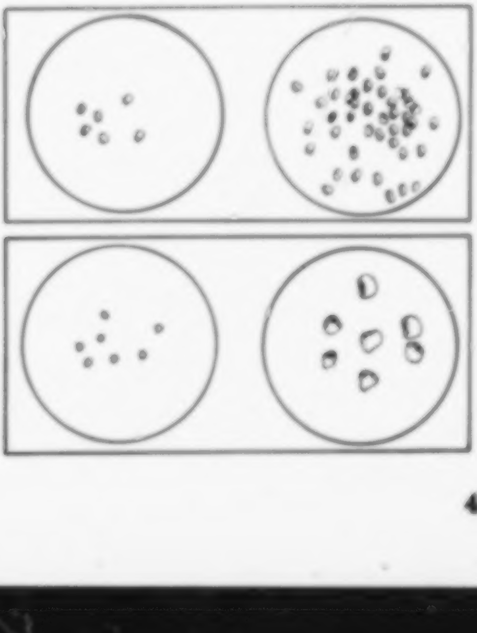
Sources of Particulate Matter



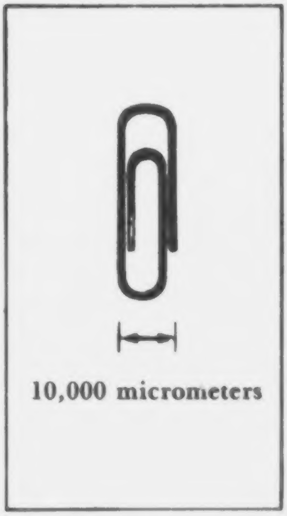
Types of Suspended Particles

- nontoxic
- intrinsically toxic
- nontoxic, but inhibit removal of toxic particles
- nontoxic, but carriers of toxic gases

Effect of toxicity is modified by

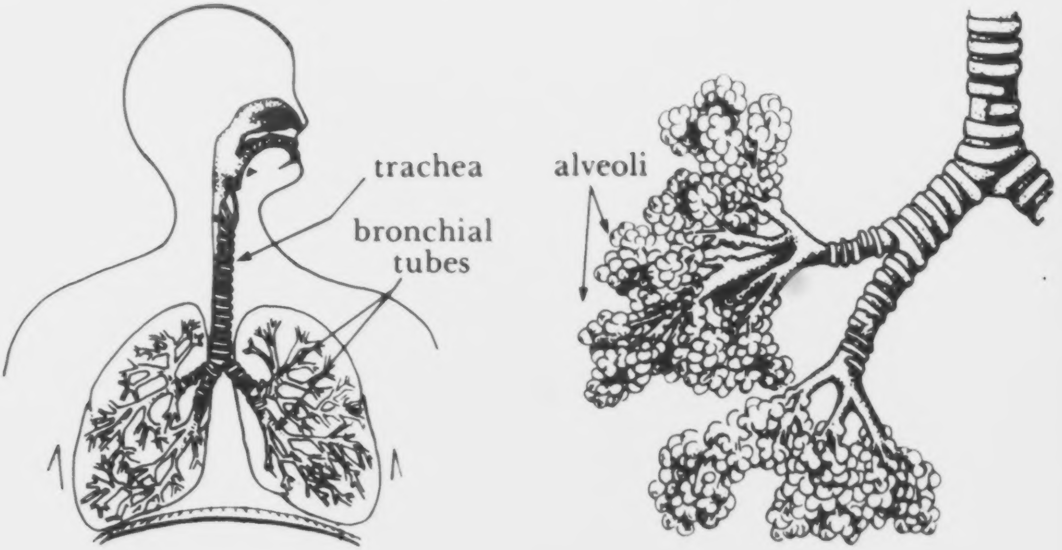


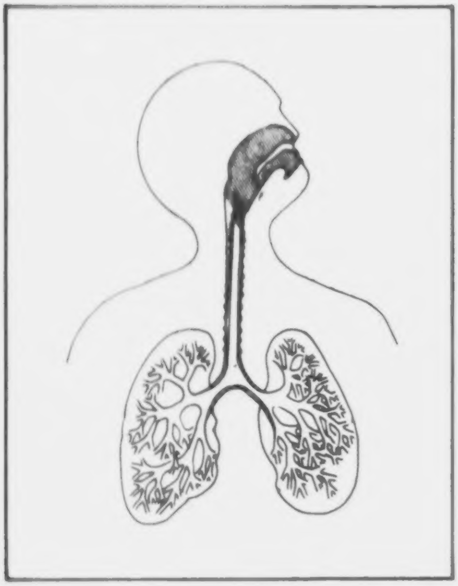
- number of particles
- size of particles


10,000 micrometers

It would take 10,000 particles, each 1 micrometer in diameter, laid end-to-end to stretch across the width of a small paper clip.

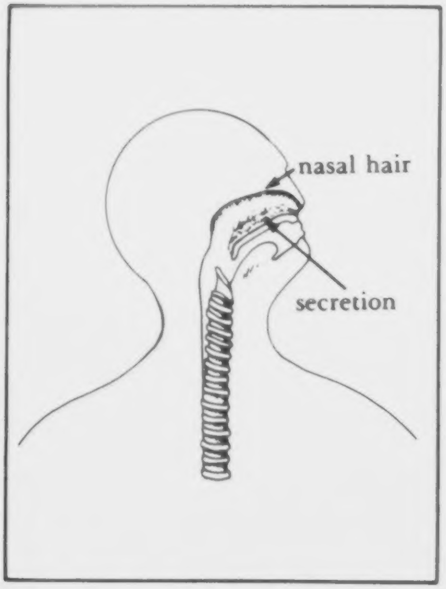
Human Respiratory System


trachea
bronchial tubes
alveoli



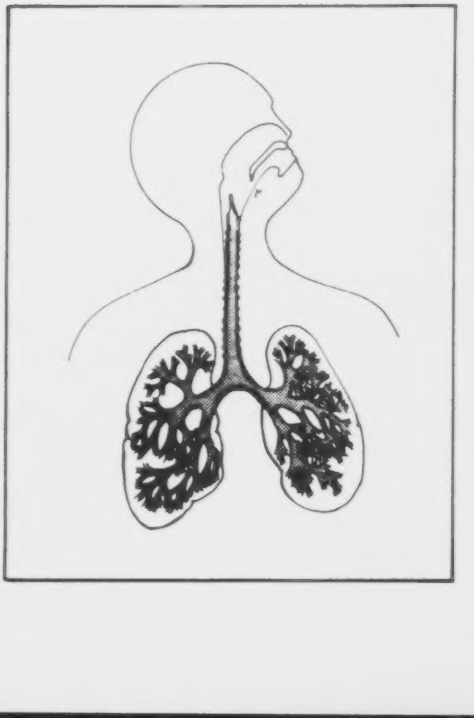
Particles ≥ 10 micrometers

collect in upper part
of respiratory system


nasal hair
secretion

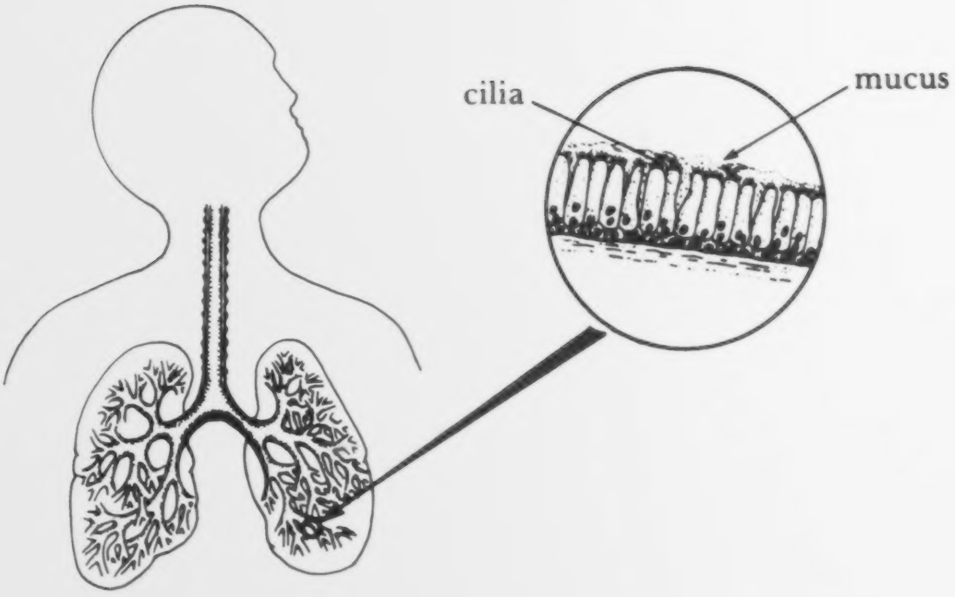
Nasal hair and warm, humid conditions of nasal passages act together to remove particles.

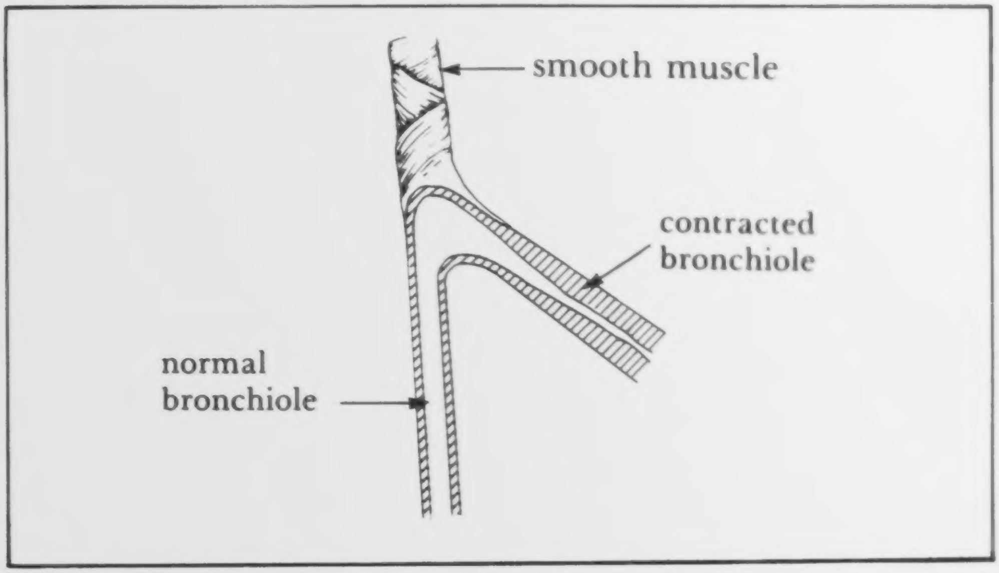
Particles collect moisture as they move through moist air of upper respiratory region, making them heavier and causing them to strike walls of throat, nose, etc. They are eliminated by sneezing, coughing, noseblowing, and spitting, or by the digestive system.



Particles 1 to 10 micrometers

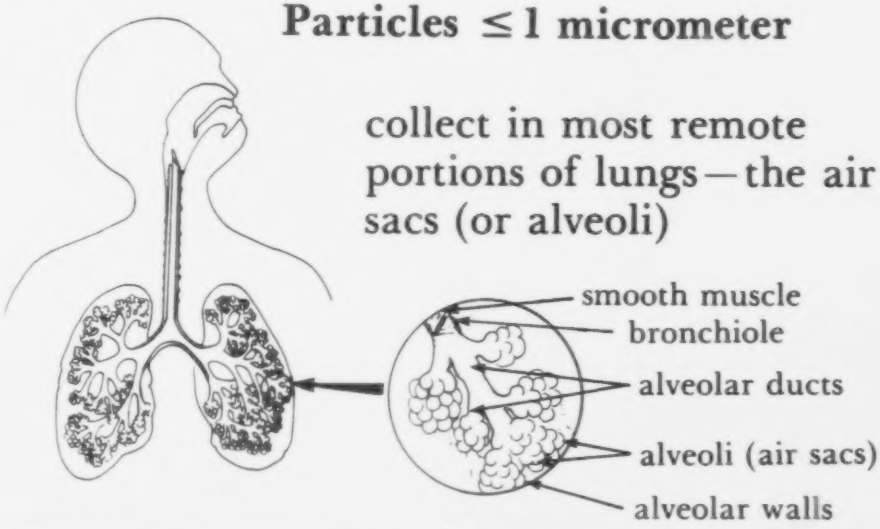
collect in middle part of respiratory system — the tracheobronchial region

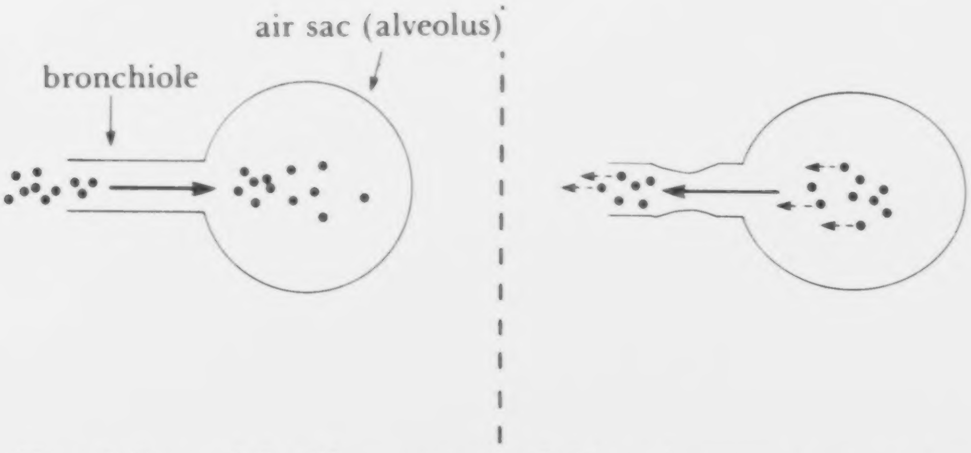

cilia
mucus


smooth muscle
contracted bronchiole
normal bronchiole

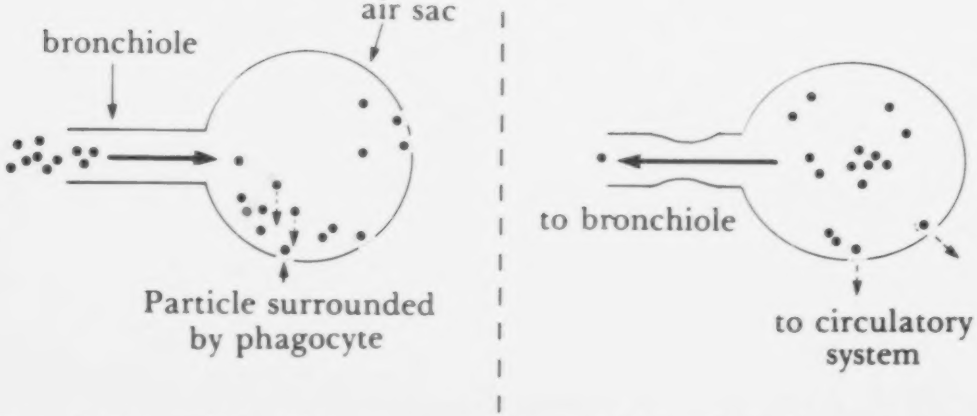
Particles ≤1 micrometer

collect in most remote portions of lungs—the air sacs (or alveoli)

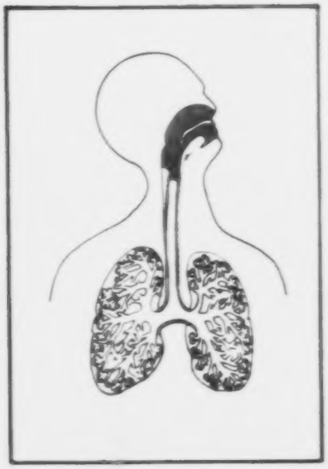

smooth muscle
bronchiole
alveolar ducts
alveoli (air sacs)
alveolar walls


air sac (alveolus)
bronchiole

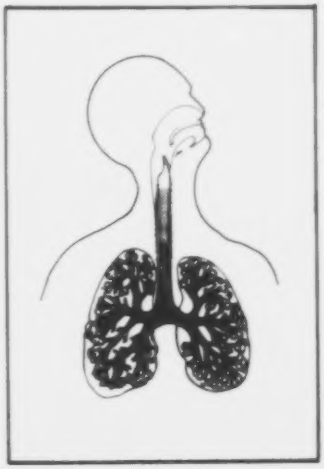
Particles with diameters of ½ micrometer or less float in the air sac and are expelled with the next breath or two.


air sac
bronchiole
Particle surrounded by phagocyte
to bronchiole
to circulatory system

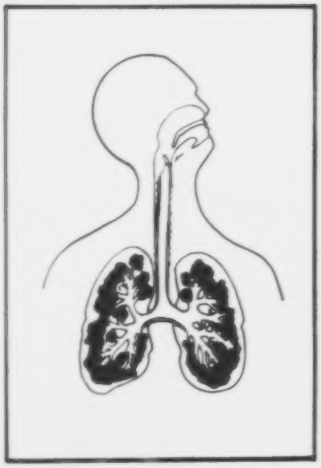
Particles with diameters from ½ to 1 micrometer are captured by phagocytes and eliminated.



Filtration and Preconditioning System



Impaction and Mucus-transport System



Pulmonary Clearing Mechanism

Health Effects—Nontoxic Particles

Concentration of Particles in $\mu g/m^3$	Effect
2000 $\mu g/m^3$ with 0.4 ppm SO_2 (24-hr avg.) episodes of several days duration	Increase in deaths due to bronchitis
1000 $\mu g/m^3$ with 0.25 ppm SO_2 (24-hr avg.) during episodes	Increases in mortality from all causes including respiratory and cardiac disease
300 $\mu g/m^3$ with 0.21 ppm SO_2 (24-hr avg.)	Significant increase in bronchitis symptoms
130 $\mu g/m^3$ with SO_2 (annual avg.)	Increase in frequency and severity of lower respiratory illness
100-200 $\mu g/m^3$ with 0.05 to 0.08 ppm SO_2 (average seasonal levels)	Increases in incidences of bronchitis reported above this level

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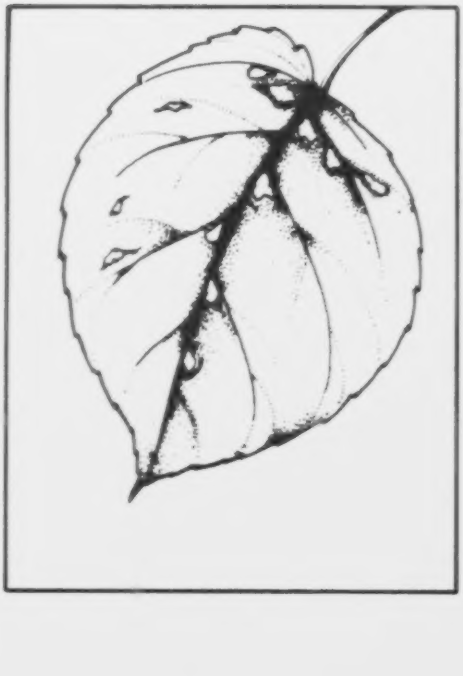
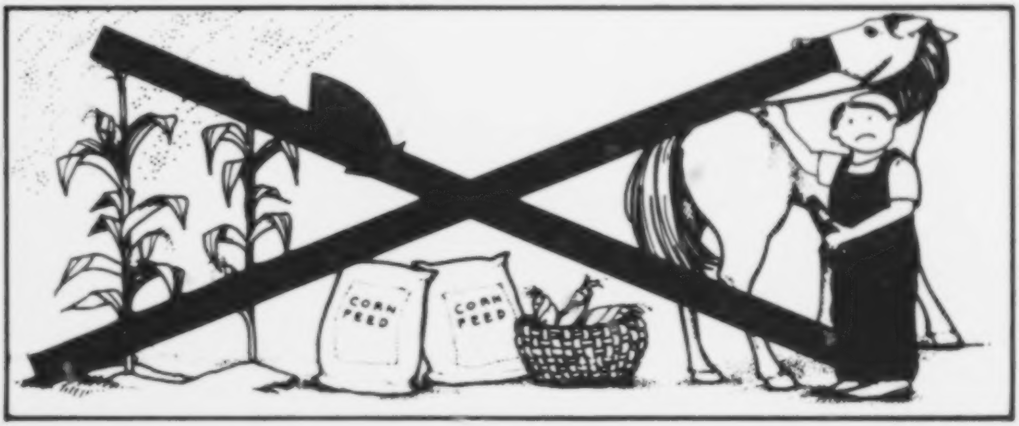
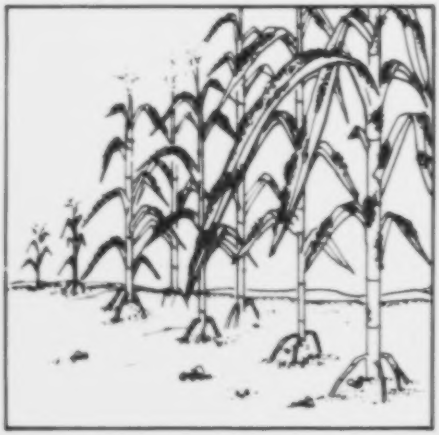


Particles such as sulfates and nitrates interact with moisture on leaves. The result is a buildup of acid which burns holes in leaves.

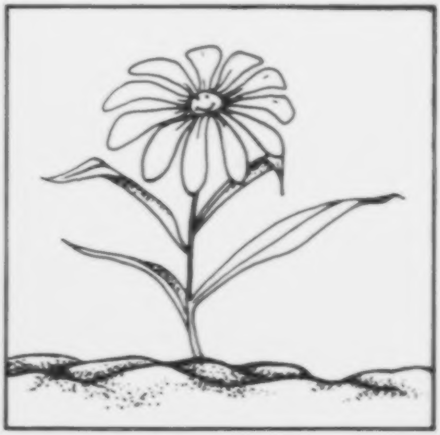
Animal feed, either raw vegetation or processed feed, can convey or absorb particulate pollutants, thus rendering the feed unusable or unsafe.



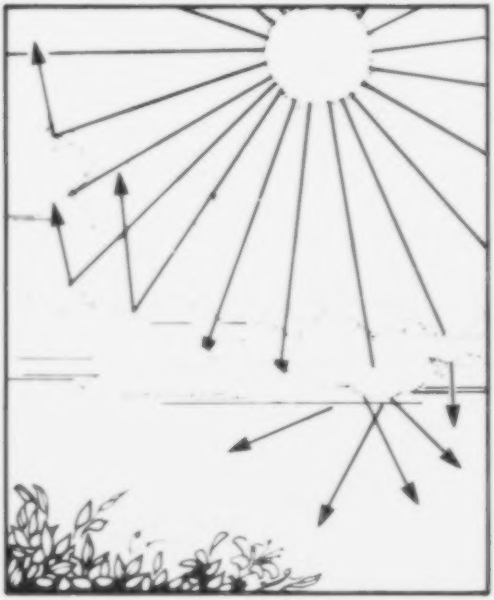
Particulate matter may be either harmful, harmless, or beneficial to plants.



Encrusted Leaves



Enriched Soil

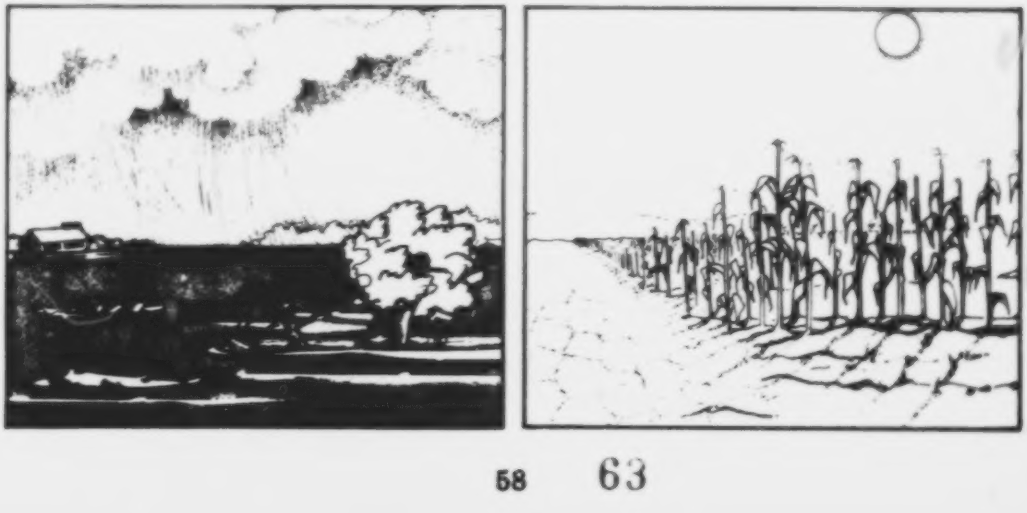


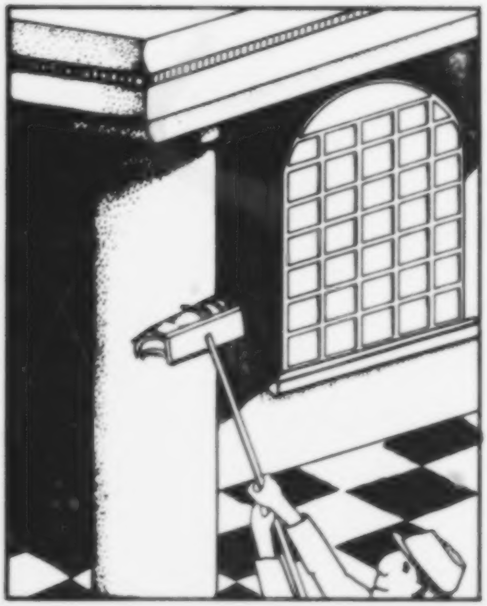
Particulate matter may
  - absorb light
  - scatter light
  - reflect light

Reduction in light available for photosynthesis and heating

Decreased visibility

Particulate matter can affect precipitation patterns.





Millions of dollars are spent each year to clean items soiled by suspended particulate matter.

Lesson III Questions

1. List the three major physical characteristics of suspended particulate matter.
2. What are the two major factors that may modify the toxicity of suspended particulate matter?
3. Match each of the three respiratory regions listed with its particle removal system.
    - i. upper respiratory region
    - ii. tracheobronchial region
    - iii. lower respiratory region
    - a. filtration and preconditioning
    - b. bronchioclarification
    - c. mucus filtration and elimination
    - d. pulmonary clearing mechanism
    - e. impaction and mucus-transport
4. Choose the term that best completes the sentence: "Cilia are. . . ."
    - a. air sacs.
    - b. small bronchial tubes.
    - c. blood cells.
    - d. small hair-like cells.
    - e. small pollutants.
    - f. bacteria-like microbes.

5. Which of the following are ways that suspended particulate matter affects visible light?

a. reflects it	d. changes its physical characteristics
b. scatters it	e. absorbs it
c. bends it	f. changes its color

6. The toxic effect of particulate matter is related to:
   - a. the toxicity of the particulate matter.
   - b. the toxicity or damaging potential of adsorbed substances.
   - c. inhibition of the removal of other toxic substances.
   - d. all of the above.

7. Incidences of respiratory and cardiac disease tend to ________ (increase/decrease) with increasing ambient concentrations of particulate matter.

8. Economic benefits from cleaning up particulate air pollution include:

a. soiling cost reductions	c. lower health costs
b. improved visibility	d. all of the above.

Lesson III
Answers

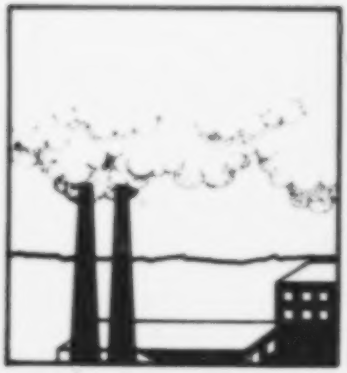
1. very small particles
   solid or liquid
   float in air/settle very slowly
2. size of particles; number of particles
3. i. a. filtration and preconditioning
   ii. e. impaction and mucus-transport
   iii. d. pulmonary clearing mechanism
4. d. small hair-like cells
5. a., b., e. reflects it, scatters it, absorbs it
6. d. all of the above.
7. increase
8. a and c, soiling cost reductions, lower health costs

Lesson IV: Sulfur Dioxide

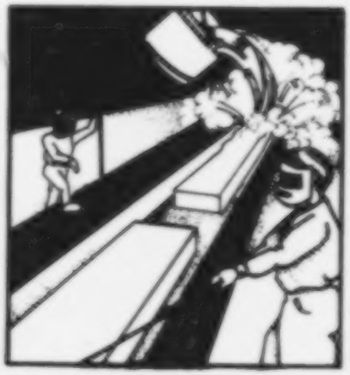
Objectives

1. Describe the relative toxicity of SO_2, SO_2 combined with particulate matter, and SO_2 combined with moisture.
2. Name the substances that are produced when sulfur dioxide combines with moisture.
3. Identify the types of respiratory problems humans may have when they are chronically exposed to SO_2.
4. Explain what is meant by "dose" as it pertains to air pollution.

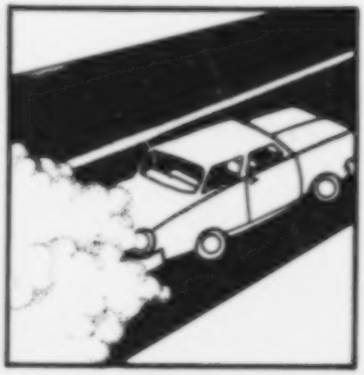
Sources of Sulfur Dioxide (SO_2)



Coal and oil combustion in boilers and furnaces



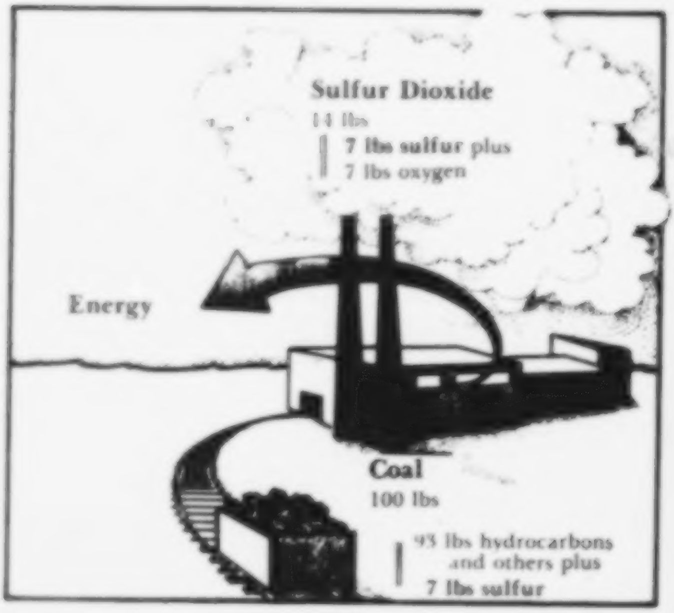
Industrial processes (such as copper smelting)

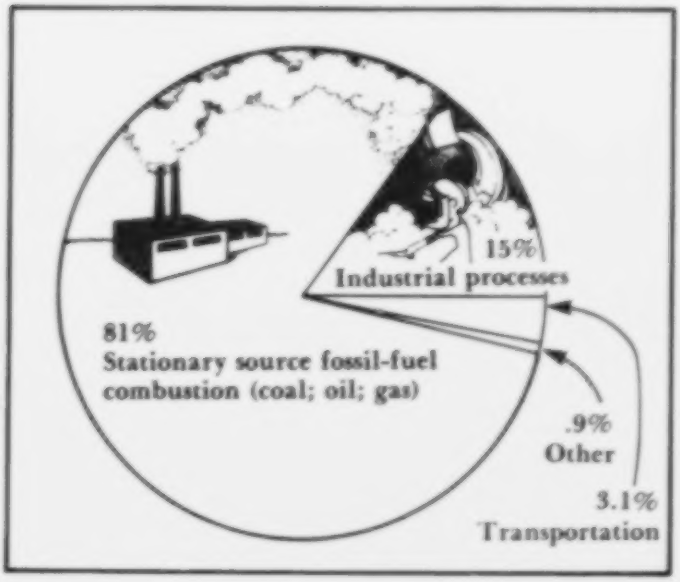


Combustion in motor vehicle engines

Sulfur Dioxide

the "pass through" pollutant

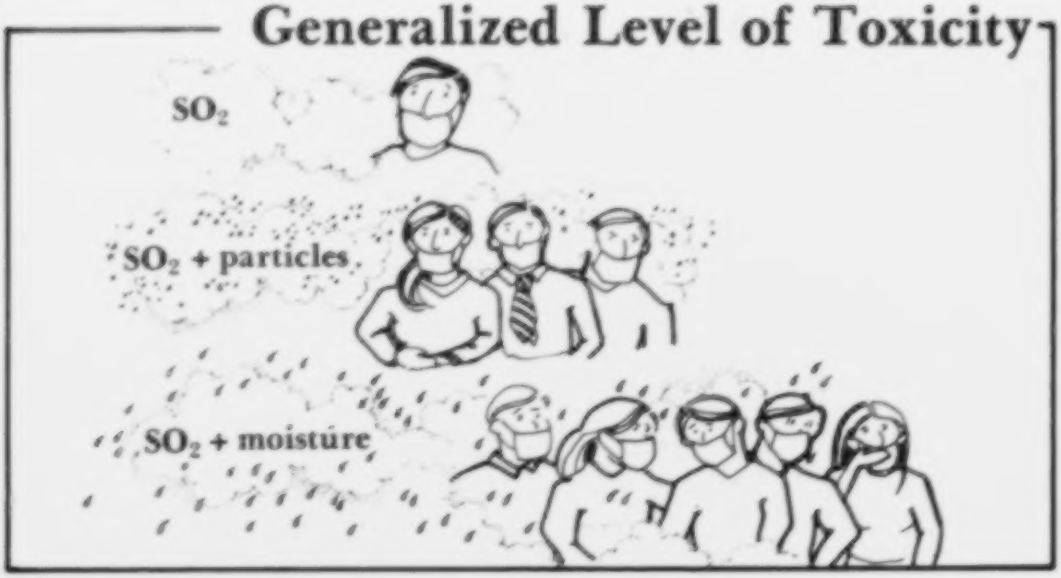

Sulfur Dioxide
14 lbs
7 lbs sulfur plus
7 lbs oxygen
Energy
Coal
100 lbs
93 lbs hydrocarbons and others plus
7 lbs sulfur



Sulfur Dioxide Emissions in the U.S.

Synergistic Effect of SO_2 and Small Particles

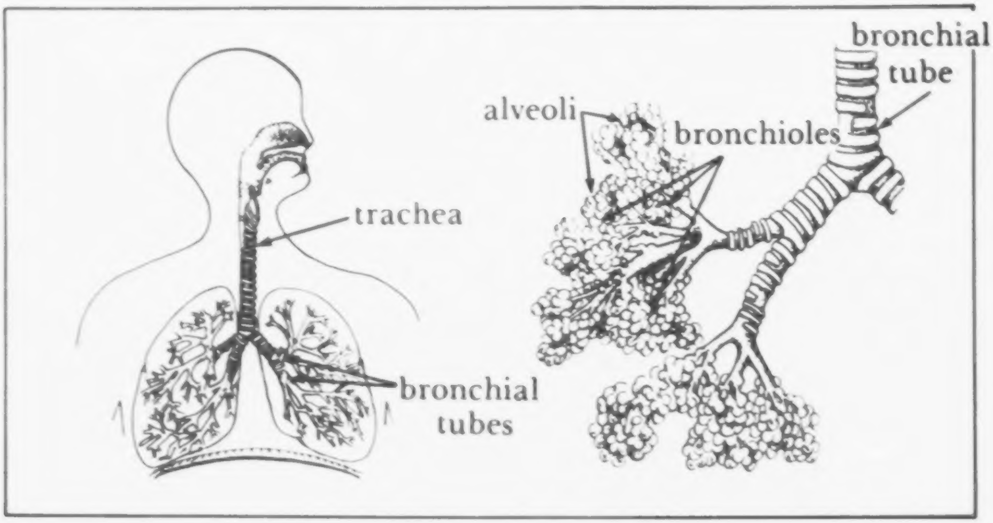
Effect of SO_2 + Effect of small particles ➡ Worse effect than the simple sum of the individual effects

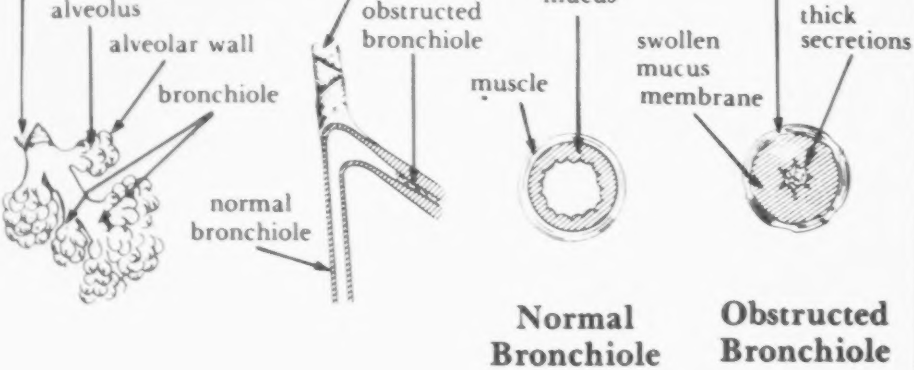

Generalized Level of Toxicity
SO_2
SO_2 + particles
SO_2 + moisture

Effects on Respiratory System

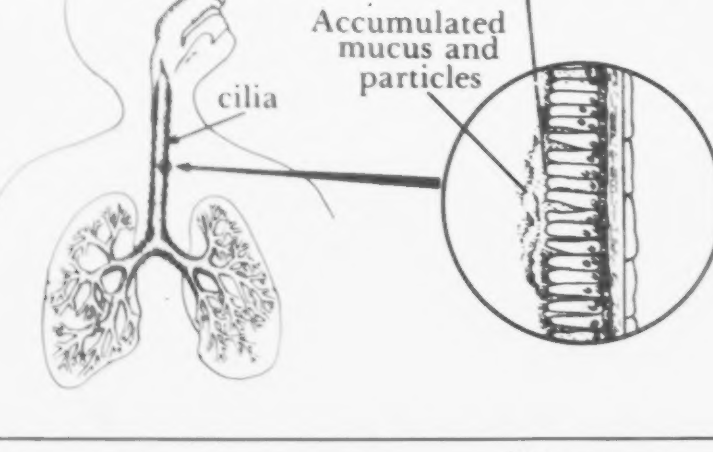
- increased resistance to air movement in and out
- decreased ability of lungs to get rid of foreign matter
- adverse changes in the respiratory tissues
- increased susceptability of lungs to disease

Human Respiratory System

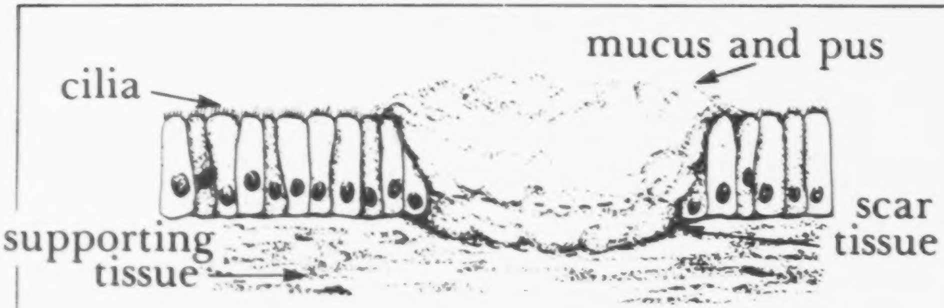

trachea
bronchial tubes
alveoli
bronchioles
bronchial tube


smooth muscle
alveolus
alveolar wall
bronchiole
smooth muscle
obstructed bronchiole
normal bronchiole
muscle
mucus
muscle in spasm
swollen mucus membrane
thick secretions

Alveoli **Bronchiole** **Normal Bronchiole in Cross Section** **Obstructed Bronchiole in Cross Section**


nonfunctioning cilia
Accumulated mucus and particles
cilia

Permanently Damaged Bronchial Wall


mucus and pus
cilia
scar tissue
supporting tissue

The cilia that bear mucus are destroyed. Their supporting tissue is replaced by scar tissue.

Small particles can adsorb sulfur dioxide and with water form acid-containing particles which irritate the respiratory system and damage the cells that line the system.

Humans chronically exposed to SO_2 have a higher incidence of

- coughs
- shortness of breath
- bronchitis
- fatigue
- "colds" of long duration

Health Effects

Concentration of SO_2 (in parts per million)	Effect
0.52 with particulates (24-hr avg. concentration)	increased deaths
0.25 with smoke (3 to 4 days; 24-hr avg.)	increased deaths
0.25 with particulates (3 to 4 days; 24-hr avg.)	increased illness for elderly
0.19 with low particulate level (24-hr mean concentration)	increased deaths
0.11 to 0.19 with low particulate level (episodes of several days duration)	increased hospitalization
.037 to 0.092 with smoke (chronic exposure)	increased respiratory symptoms and lung diseases

Factors Affecting a Plant's Response to Pollution

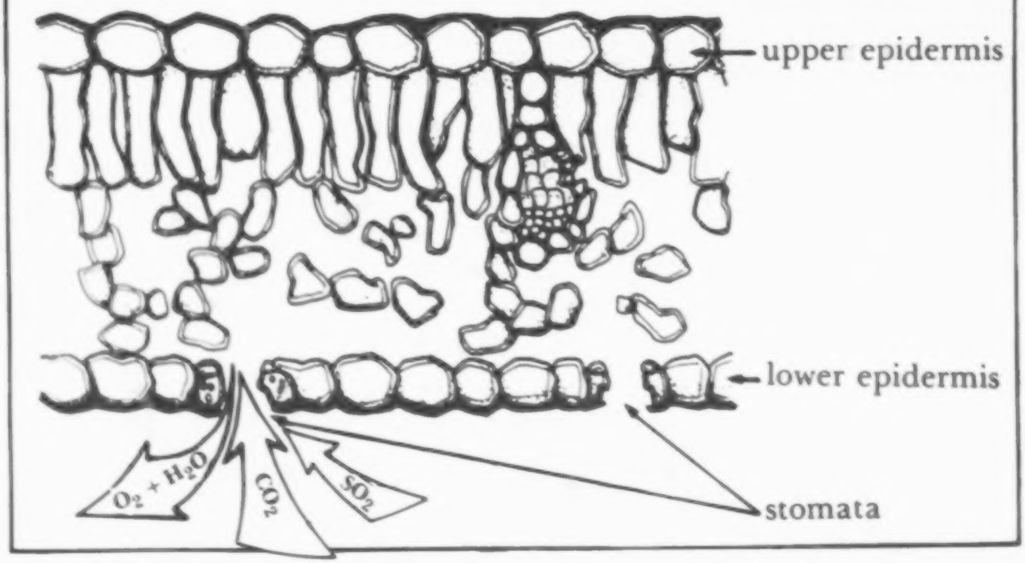
- climate
- light
- temperature
- humidity
- nutrition

In general, conditions which favor plant growth tend to increase the plant's sensitivity to air pollution.

Dose...

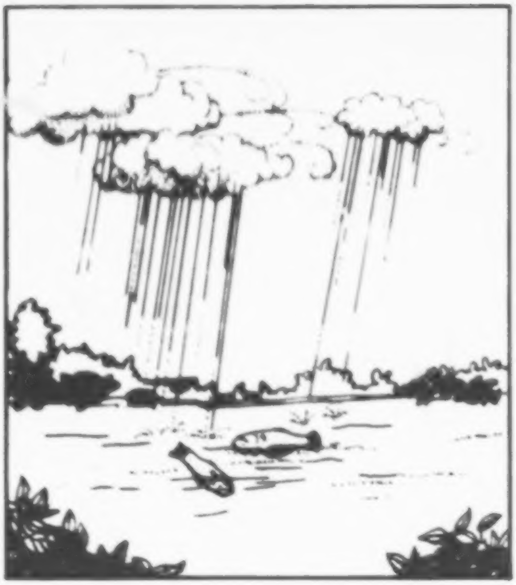
the concentration of the pollutant and the length of time that the subject is exposed to that pollutant

Cross-Section of a Leaf


upper epidermis
lower epidermis
$O_2 + H_2O$
CO_2
SO_2
stomata

Relative Sensitivity of Plants to SO_2

	Sensitive	Tolerant
Crops	Alfalfa	Celery
	Buckwheat	Corn
	Barley	Onion
Flowers	Sweet Pea	Lilac
	Four O'Clock	
	Cosmos	
Trees	Trembling Aspen	Cedar
	Jack Pine	Citrus
	White Pine	Maple
Garden plants	Peas	Musk melon
	Rhubarb	Potato
	Spinach	Broccoli



Acid Rain

- acidification of lakes with destruction of aquatic life
- makes soil more acid—usually detrimental—but can be beneficial

SO_2 can cause damage to

- building materials
- cloth
- metals

and can also result in decreased visibility when sulfate particles form in the air.

Lesson IV
Questions

1. Arrange the following in order of toxicity—from most toxic to least toxic.
    a. SO_2 in combination with particulate matter
    b. SO_2 alone
    c. SO_2 in combination with moisture
2. Name the two substances that are produced when sulfur dioxide combines with moisture.
3. Which of the following problems may humans have after chronic exposure to sulfur dioxide?
    a. coughs
    b. fatigue
    c. bronchitis
    d. colds of longer duration
    e. shortness of breath
    f. all of the above
4. In the study of air pollution, "dose" refers to which of the following?
    a. the concentration of the pollutant
    b. the length of exposure to the pollutant
    c. the toxicity of the pollutant
    d. a and c, above
    e. a and b, above

Lesson IV
Answers

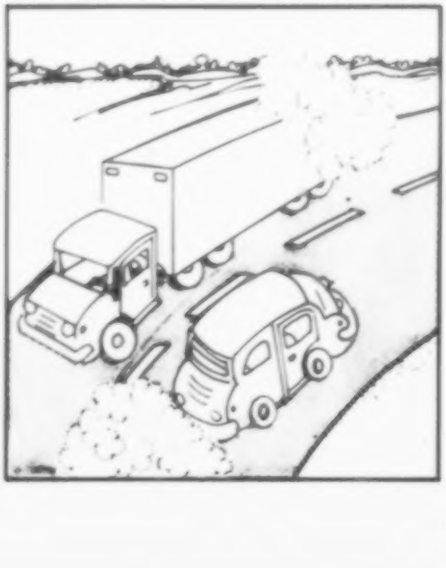
1. c. SO_2 combined with moisture
    a. SO_2 combined with particulate matter
    b. SO_2 alone
2. sulfurous acid (H_2SO_3); sulfuric acid (H_2SO_4)
3. f. all of the above
4. e. (a and b, above); the concentration of the pollutant, the length of exposure to the pollutant

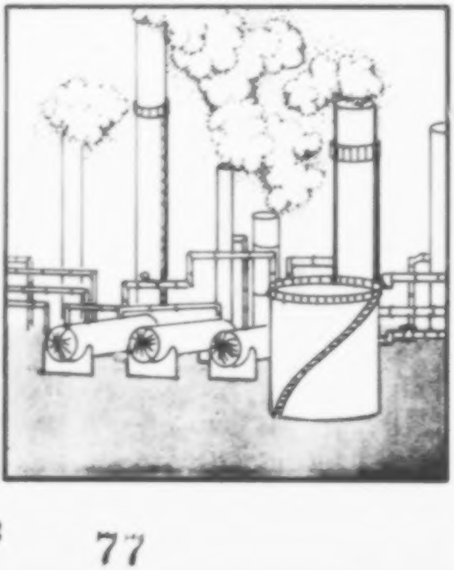
Lesson V: Carbon Monoxide

Objectives

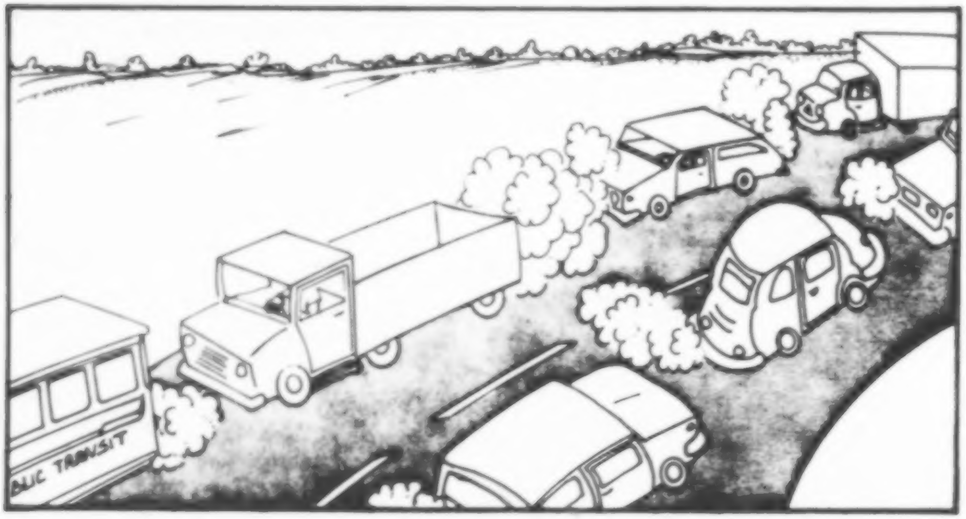
1. Describe the type of area where one finds the highest concentration of carbon monoxide in the air.
2. Describe how carbon monoxide affects gas exchange in our blood.
3. Name the two types of diseases most likely to be aggravated by exposure to carbon monoxide.
4. List the four segments of our population most likely to be adversely affected by exposure to carbon monoxide.

Sources of Carbon Monoxide

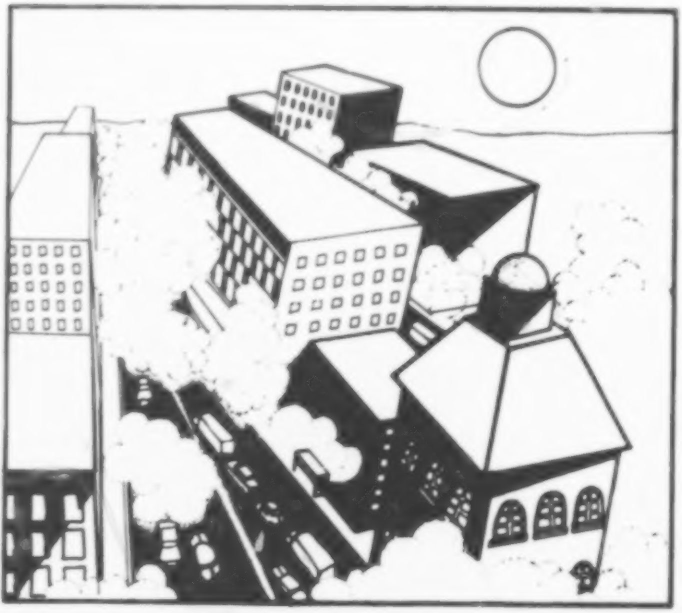




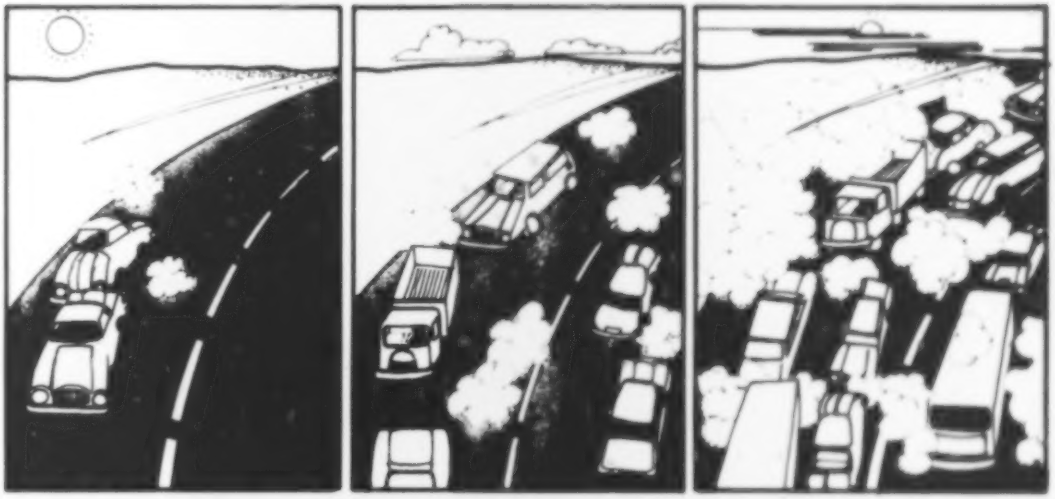
Transportation accounts for about 80% of man-made CO emissions in the U.S.



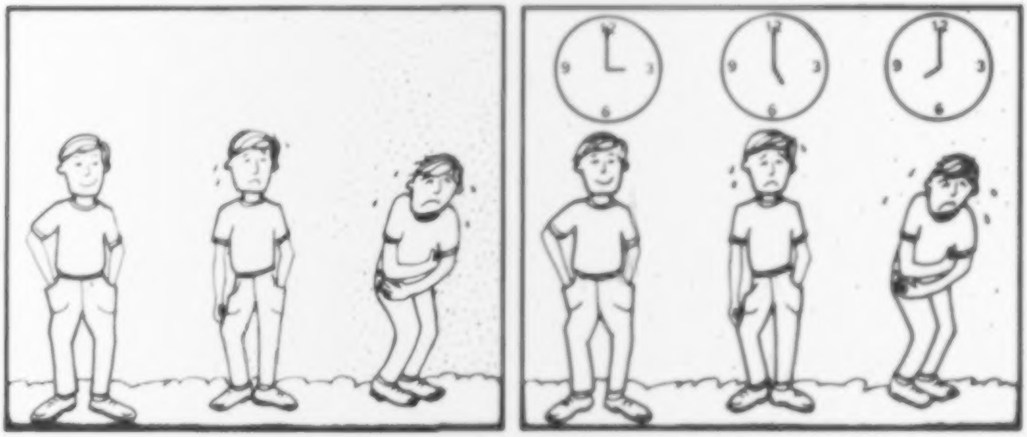
The most severe CO problems are found in cities—where vehicle emissions are concentrated between rows of tall buildings.



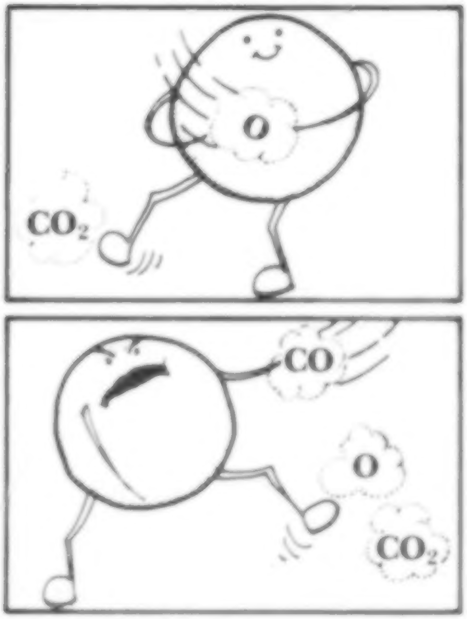
The ambient concentration of carbon monoxide on a particular day depends upon the number of vehicles and the weather.



The effects of carbon monoxide are dependent upon both

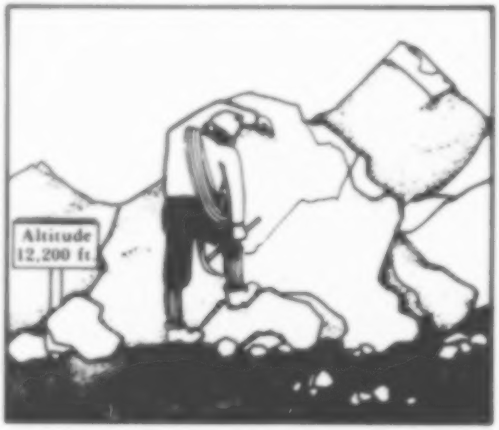


- concentration
- duration

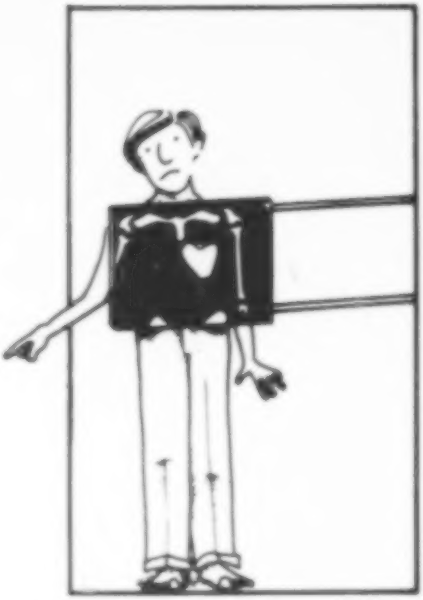


Oxygen transport cells usually replace carbon dioxide with oxygen. However, in the presence of carbon monoxide, they will replace the oxygen and carbon dioxide with carbon monoxide. This reduces the supply of oxygen to the body.

The effect of CO intoxication is similar to that of anemia or hypoxia. It reduces the supply of oxygen to the body tissues.

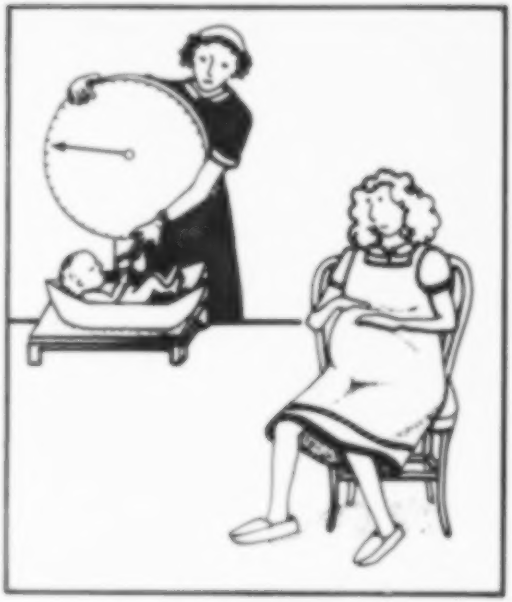


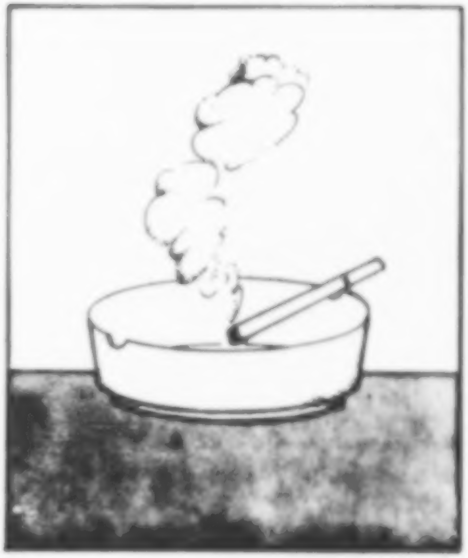
Under ambient conditions, carbon monoxide intoxication is likely to aggravate existing physical conditions. Under acute conditions, it may result in death.



Carbon monoxide in amounts found in some major metropolitan areas can lead to increased hospitalization for heart and circulatory system related disease.

The newborn and unborn are also affected by carbon monoxide. The ambient levels in highly polluted urban areas are associated with lower birthweight and increased deaths of newborns.





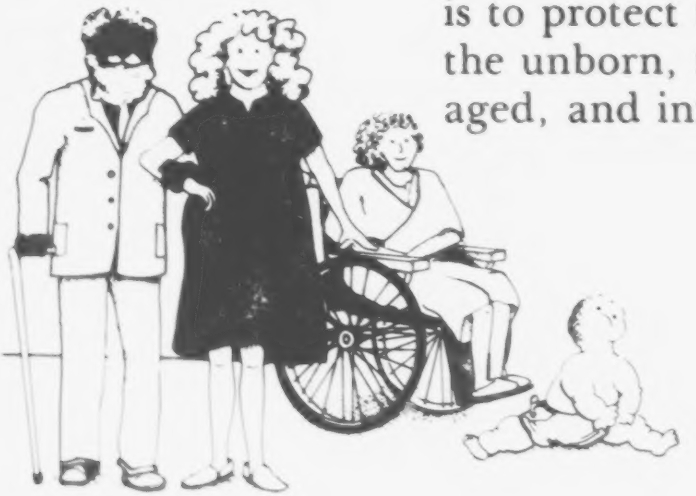
Smokers inhale a significant amount of CO

Behavior is not significantly impaired by concentrations of carbon monoxide which are below the NAAQS.

- OK VIGILANCE
- OK REACTION TIME
- OK DRIVING BEHAVIOR
- OK DISCRIMINATION
- OK COORDINATION
- OK COMPLEX BEHAVIOR

Health Effect

Concentration of CO (in ppm)	Effect
High concentration Greater than 100 ppm for 10 minutes	Physiological stress on patients with heart disease
100 ppm – intermittently	Impaired performance in psychomotor tests
50 ppm – for 90 minutes	Impaired time-interval discrimination for nonsmokers
30 ppm – for up to 12 hours	Elevated carbon in hemoglobin levels – reduced oxygen transport



The principal reason for controlling carbon monoxide emissions is to protect the health of the unborn, newborn, aged, and infirm.

Lesson V
Questions

1. In which type of area would one be most likely to find the highest concentration of carbon monoxide?
   - a. desert
   - b. rural
   - c. forest
   - d. suburban
   - e. urban
   - f. wilderness
2. Describe how carbon monoxide affects gas exchange in our blood.
3. Name two types of diseases most likely to be aggravated by carbon monoxide.
4. Which of the following is a segment of our population *least* likely to be severely affected by exposure to ambient carbon monoxide?
   - a. newborn
   - b. young adults
   - c. very old
   - d. unborn
   - e. infirm

Answers are on the next page.

Lesson V
Answers

1. e. urban
2. Carbon monoxide displaces oxygen in the red blood cells, thus depriving the body tissues of oxygen.
3. circulatory disease
   heart diseases
4. b. young adults

Lesson VI: Nitrogen Dioxide

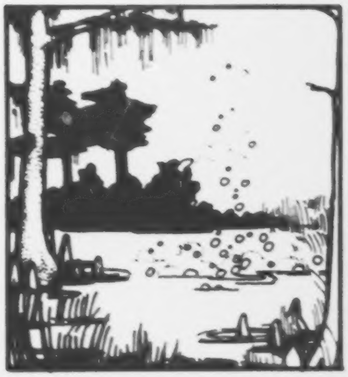
Objectives

1. Identify which is most toxic to humans, nitric oxide or nitrogen dioxide.
2. Identify three effects of oxides of nitrogen on materials.
3. Identify a disease associated with increased ambient levels of NO_2.
4. List two effects of NO_2 on materials.

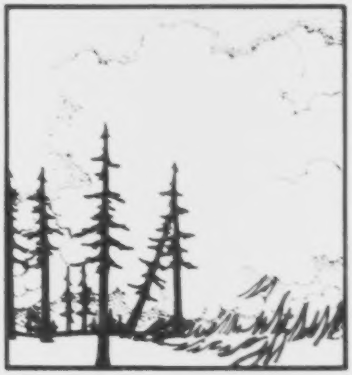
Oxides of Nitrogen

- **NO** — nitric oxide
- **NO_2** — nitrogen dioxide
- **NO_X** — combination of all nitrogen oxides

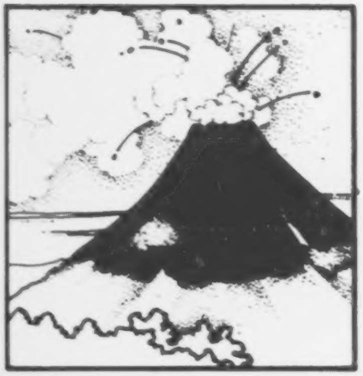
Natural Sources of Nitrogen Oxides



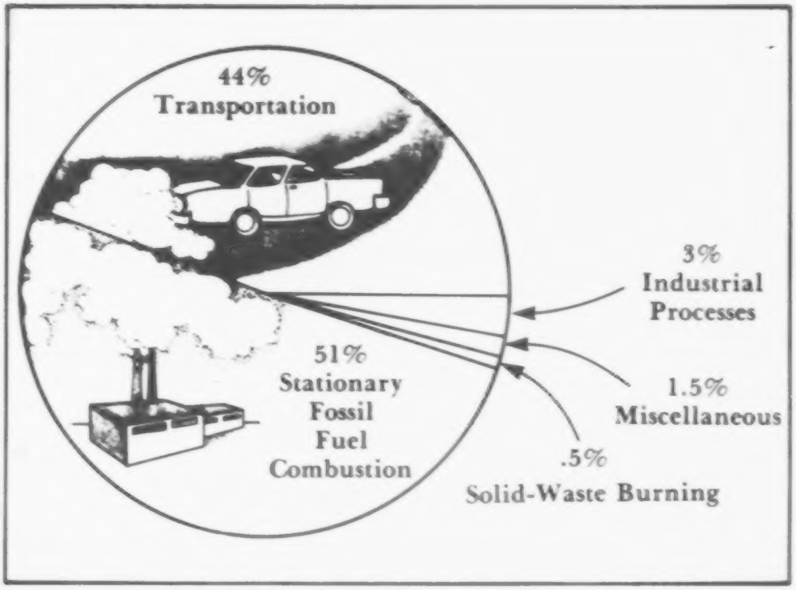
Reduction of Organic Nitrates



Forest and Grass Fires



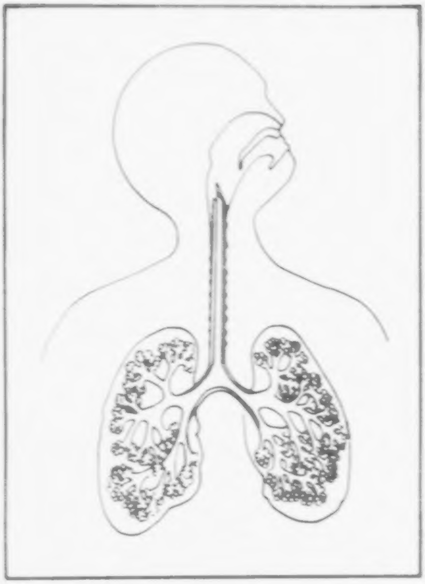
Volcanoes



Manmade Sources of Nitrogen Oxides

Nitric Oxide (NO)

- not very toxic at ambient levels
- is rapidly converted to nitrogen dioxide which is toxic
- at concentrations far above those observed in cities, it can cause disturbance in the
    - central nervous system
    - circulatory system
    - enzyme system



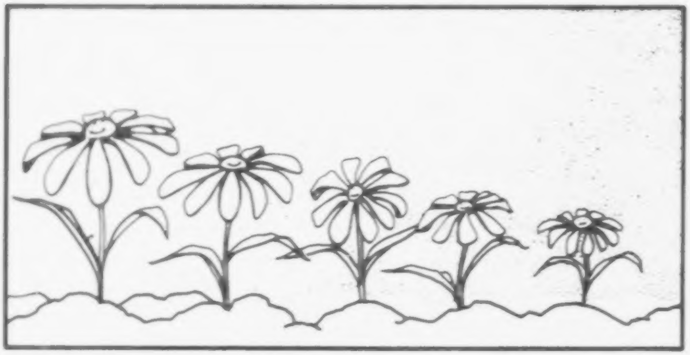
Nitrogen Dioxide

Because of its low solubility in water, nitrogen dioxide penetrates to the most remote portions of the respiratory tract, the alveoli.

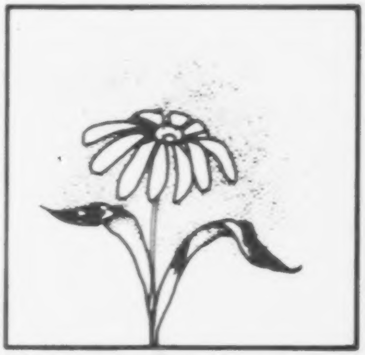
NO_2 Health Effects

Concentration of NO_2 (in parts per million)	Effect
150 ppm (5 to 8 minutes)	Potentially fatal
50 to 100 ppm (< 1 hr)	May produce bronchopneumonia – but recovery probable
10 to 40 ppm (intermittent exposure)	May produce chronic fibrosis and emphysema
.05 to 0.10 ppm (chronic exposure)	Evidence of increases in chronic bronchitis
< .05 ppm (long-term average)	Evidence of increases in heart and lung disease in general population with increasing ambient NO_2 concentrations

Effects of NO_2 on Plants

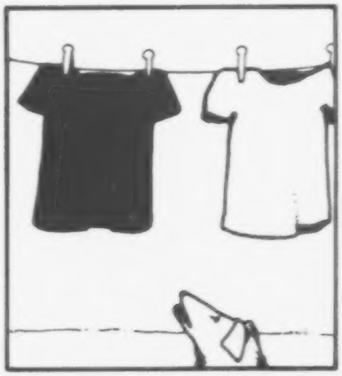


Reduction in plant size
(Primary Effect)

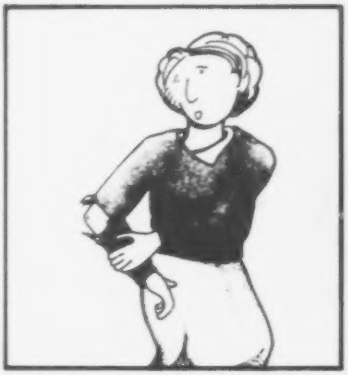


Much higher
concentrations
cause leaf
spotting

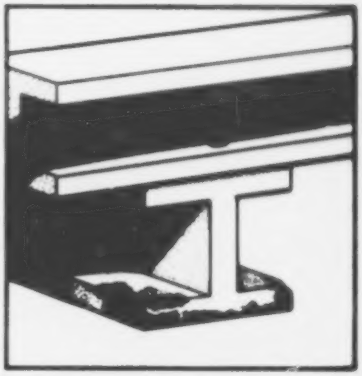
Effects of NO_2



Dyes change
colors



Fabrics lose
strength



Some metals
corrode

Lesson VI
Questions

1. Which is most toxic to humans, nitric oxide or nitrogen dioxide?
2. Which of the following are effects of exposure to oxides of nitrogen?
   a. metal can be damaged
   b. fabrics loose strength
   c. dyes change colors
   d. only a and b, above
   e. a, b, and c, above
3. Which of the following is associated with increased ambient levels of NO_2?
   a. apoxia
   b. neurosis
   c. bronchitis
   d. all of the above.
4. Describe two effects that NO_2 may have on materials.

Lesson VI
Answers

1. Nitrogen dioxide
2. e. (a, b, and c) metal can be damaged, fabrics loose strength, and dyes change colors
3. c. bronchitis.
4. Any two from the following list:
   fades dyes
   fades paints
   deteriorates synthetic fabrics
   discolors fabrics
   corrodes metals

Lesson VII:
Hydrocarbons*—Volatile Organic Compounds
Objectives

1. List the three major sources of volatile organic compounds emitted into the ambient air.
2. State three reasons why volatile organic compounds are controlled.
3. Identify three effects on human health of the more toxic hydrocarbons and volatile organic compounds.
4. Identify the volatile organic compound which adversely affects ornamental plants.

* NOTE: EPA revoked the NAAQS covering hydrocarbons on January 5, 1983. However, the Agency maintained that hydrocarbons should continue to be controlled or restricted.

Hydrocarbons and Volatile Organic Compounds

- are subject to control because of their role in the formation of ozone and other photochemical air pollutants
- many are very toxic (e.g., diethyl sulfate, tetramethyl lead)
- some are known carcinogens (e.g., benzene, vinyl chloride)

Hydrocarbons

- compounds containing only carbon and hydrogen
- many are in gaseous form at normal atmospheric conditions

Volatile Organic Compounds

- compounds containing carbon and hydrogen and other elements
- are in gaseous form at normal atmospheric conditions

Effects of Hydrocarbons and VOCs

Humans—	Effects have been noted in cases of occupational exposure to tetramethyl lead, benzene, etc.
Plants—	Ethylene is the only hydrocarbon known to cause plant damage at concentrations found in urban areas
Materials—	No known effects at concentrations found in urban areas

Lesson VII
Questions

1. Which two of the following are reasons that volatile organic compounds and hydrocarbons are controlled?
   - a. They may contribute to the formation of photochemical pollutants.
   - b. The odor of all hydrocarbons is very unpleasant.
   - c. Some are harmful, in and of themselves, to human health and welfare.
   - d. They contribute to the formation of NO_x.
   - e. They rapidly corrode metal.
2. Hydrocarbons and VOCs such as benzene and polyvinyl chloride have which of the following health effects. They are
   - a. toxic
   - b. carcinogenic
   - c. asthma-producing
   - d. all of the above.
3. Damage directly to plants and materials by VOCs and hydrocarbons:
   - a. is maximum in the winter.
   - b. is a problem only for synthetic materials.
   - c. is not considered a problem.
   - d. results in $10 million in losses each year.

Lesson VII
Answers

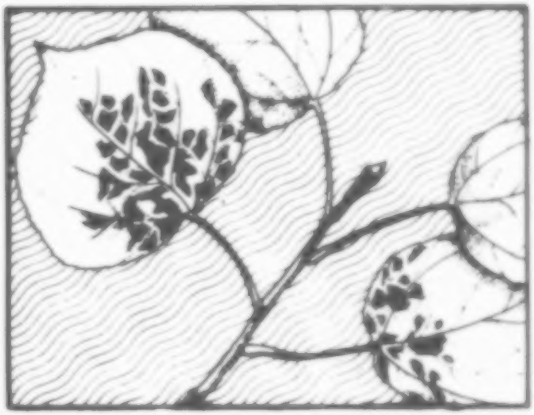
1. a, c. They may contribute to the formation of photochemical pollutants and some are harmful, in and of themselves, to human health and welfare.
2. a and b. toxic and carcinogenic
3. c. is not considered to be a problem except for certain ornamental plants and some crops at high concentrations.

Lesson VIII: Ozone

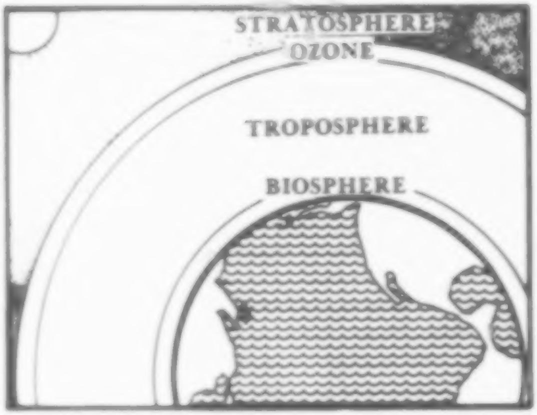
Objectives

1. Identify the most beneficial effect of ozone found in the stratosphere.
2. Name the four segments of our population most likely to be adversely affected by exposure to ozone.
3. Identify the three types of activity found in the lungs that are adversely affected by exposure to ozone.
4. Identify the effect of ozone on plants relative to the effect on plants of other air pollutants.
5. Describe the effect of ozone on exterior coatings and finishes.

Ozone



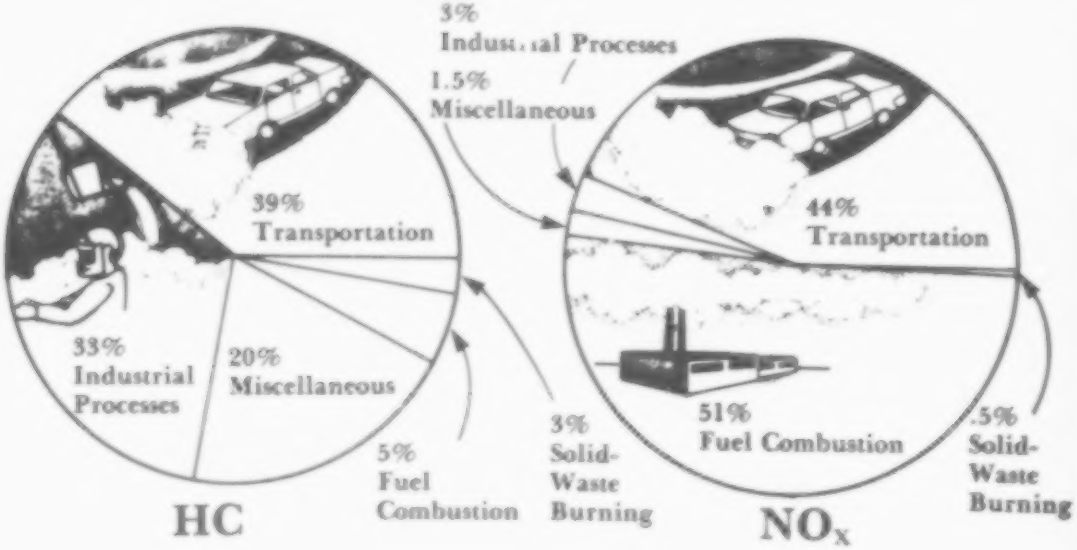
Causes injury to plants, man, and materials.



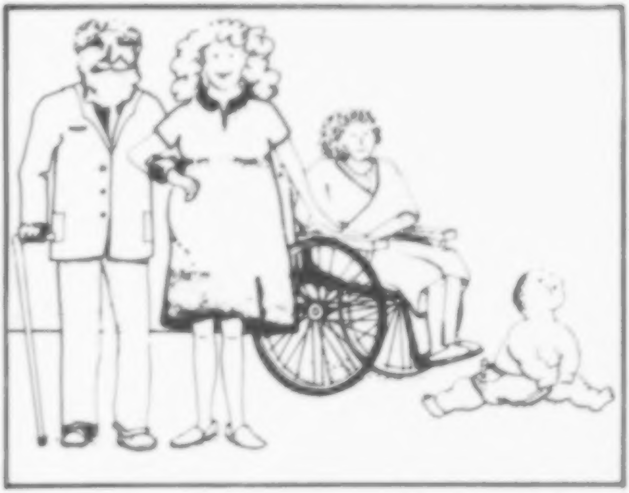
Screens out harmful ultraviolet rays.

Both natural and manmade volatile organic compounds can produce ozone, but **naturally** occurring volatile organics seldom produce enough ozone to cause substantial adverse effects.

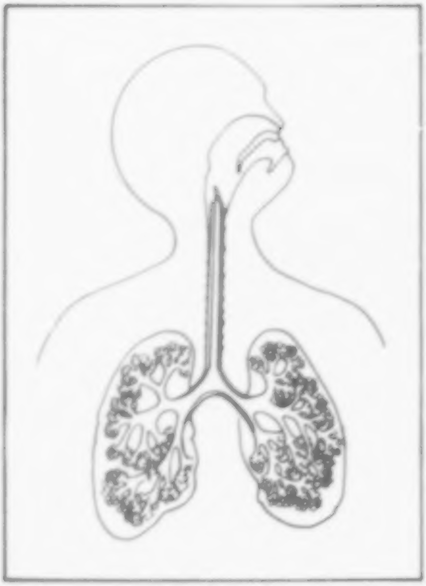
HC and NO_x Emissions in U.S.



Ozone and other oxidants cause, at least temporarily, physiological changes in humans.



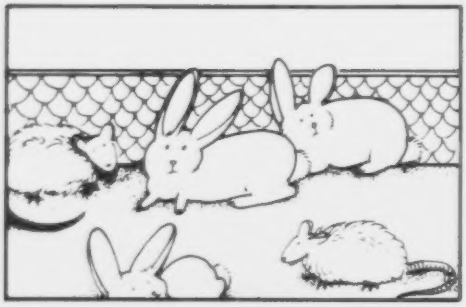
Population segments of most concern are the aged, the young, the sick, and the unborn.



The lung allows certain gases to pass from the atmosphere into the blood and vice versa.

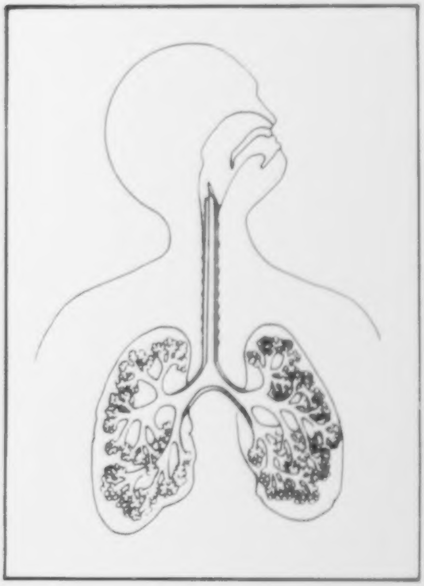
Any action which decreases the lung's ability to cause this transfer to occur rapidly and efficiently could impair health.

Healthy individuals exposed to ozone respond by decreasing the volume of air brought into the lungs. This occurs at concentrations in the 0.10—0.15 ppm or more range.



Biological effects on humans are usually predicted from an analysis of all available research. Toxicological studies of exposure of animals play an important role.

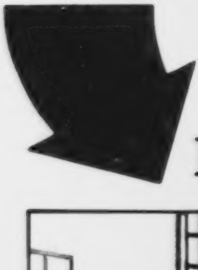
The effects on humans are projected from the animal studies.



The biochemical balance in the lung tissue is very important.

Ozone causes shifts in

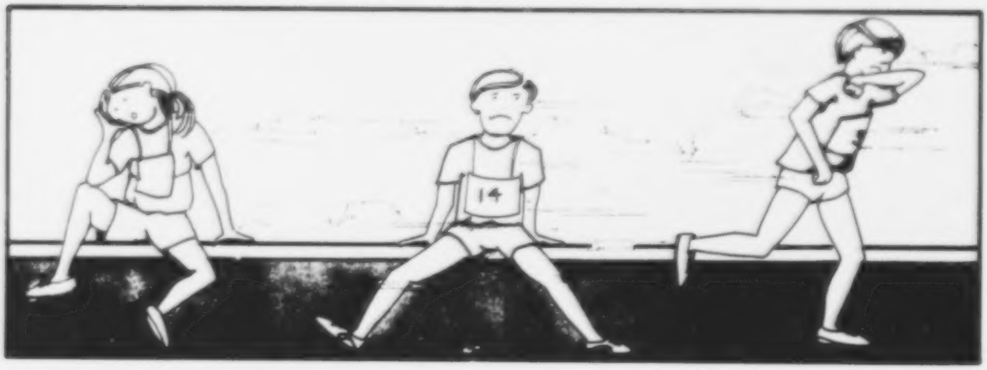
- enzyme activity
- chemical activity
- cellular activity



Increased Ambient Ozone Levels

Increased Hospital Admissions

Ozone inhalation
may reduce performance.



Other photochemical oxidants which form along with ozone are eye irritants.

Ozone probably causes more plant damage in the United States than any other air pollutant.

Threshold Doses of Ozone Needed to Cause Injury to Plants Grown Under Sensitive Conditions

Time (hrs)	Ozone concentration needed to cause injury		
	Sensitive	Intermediate	Tolerant
0.5	.15-.30 ppm*	.25-.60 ppm	≤ .50 ppm
1.0	.10-.25	.20-.40	≤ .35
2.0	.07-.20	.15-.30	≤ .25
4.0	.05-.15	.10-.25	≤ .20
8.0	.03-.10	.08-.20	≤ .15

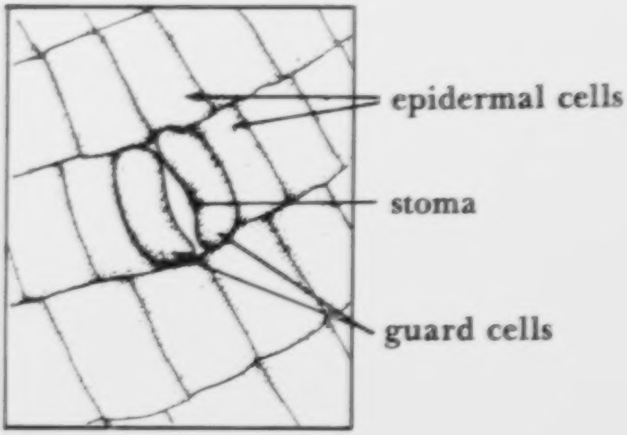
*1 ppm = 1,980 $\mu g/m^3$ at 25°C.

Source: Heggestad, H. E. & Heck, W. W. Nature, Extent, and Variations of Plant Response to Air Pollutants. *Advances in Agronomy*, 23:111-145, 1971.

Relative Sensitivity of Various Plants to Ozone

Crops and Weeds

Sensitive	Intermediate	Tolerant
Alfalfa	Cabbage	Beet
Barley	Carrot	Cotton
Bean	Corn, Field	Descurainia
Buckwheat	Cowpea	Jerusalem cherry
Citrus	Cucumber	Lamb's-quarters
Clover, Red	Endive	Lettuce
Corn, Sweet	Hypericum	Mint
Grape	Parsley	Piggy-back plant
Grass, Bent	Parsnip	Rice
Grass, Brome	Pea	Strawberry
Grass, Crab	Peanut	Sweet Potato



Stoma of Leaf (underside)

Effects of Ozone on Plants

Action	Results
• acts as oxidizing agent and attacks cells	• cell breakdown and collapse
• modifies amino acids, proteins, unsaturated fatty acids, sulfhydryl residues	• leakage of water and ions from cells
• produces ethylene	• damage in plants sensitive to ethylene
• reduces carbon dioxide fixation	• reduced plant vigor and reduced amount of new cell material produced

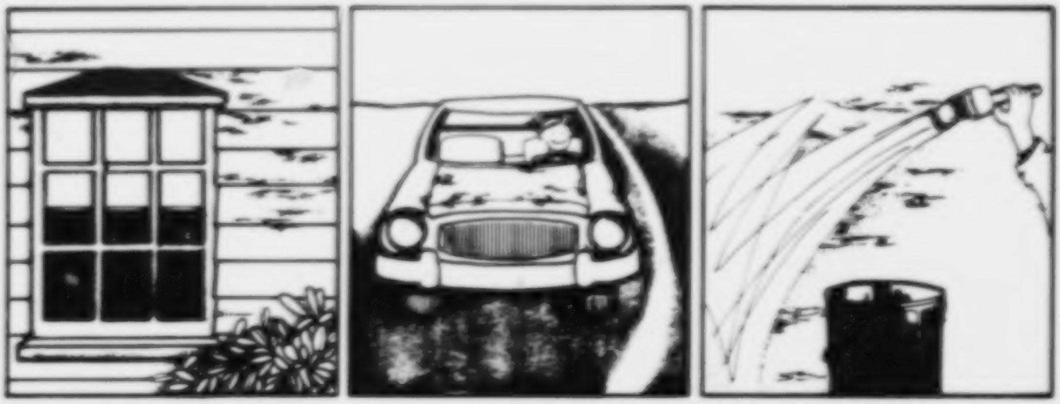
Ozone damage to plants can

- damage forests and crops
- be aesthetically unpleasing
- cause economic loss

Ozone Damage to Elastomers

(Rubber and rubberlike materials)

- Cracking will occur in sensitive elastomers
- Factors influencing ozone damage include
  - nature of the elastomeric compound
  - degree of stress
  - ozone concentration
  - exposure duration
  - rate of ozone contact with material
  - temperature
- Anti-cracking compounds are added to elastic products to control cracking.



Exterior coatings such as oil and acrylic latex, oil coatings, automotive finishes, and industrial coatings deteriorate under even low ozone concentrations.

Ozone Damage to Fabric

- Ozone can produce marked fading in most blue disperse dyes and in some red and yellow dyes.
- Fading can occur in clothes along folds and edges.

Lesson VIII
Questions

1. Which of the following describes the most beneficial effect of ozone found in the stratosphere?
   a. It scatters visible light.
   b. It creates great amounts of heat.
   c. It screens out harmful ultra-violet rays.
2. List the four segments of our population most likely to be adversely affected by exposure to ozone.
3. Which types of activity found in the lungs are adversely affected by exposure to ozone?

a. enzyme	d. only a and b
b. chemical	e. only b and c
c. cellular	f. a, b, and c

4. Choose the word that best completes the sentence.
   Ozone probably causes ______________ plant damage in the United States
   (less more)
   than any other air pollutant.
5. Describe the effect of ozone on exterior coatings and finishes.

Lesson VIII
Answers

1. c. It screens out harmful ultraviolet rays.
2. aged
   young
   sick
   unborn
3. f. (a, b, and c) enzyme, chemical, and cellular
4. more
5. They deteriorate when exposed to ozone.

Lesson IX: Lead

Objectives

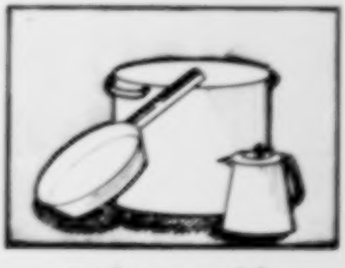
1. Identify the two major concerns that air pollution control personnel have about lead.
2. Describe the dispersion of lead emissions from urban sources.
3. Identify, in general terms, the rate at which lead is removed from the body.
4. Identify the principal mechanisms for the entry of lead into the body.
5. Describe the principal adverse effects of lead on people.
6. Describe the effect of lead on materials, vegetation, and farm animals.

Lead

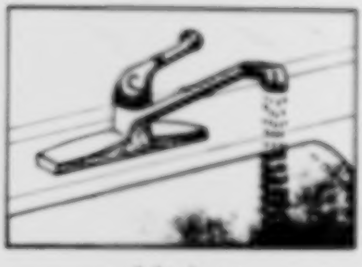
Characteristics:

- Gray metal
- Fairly abundant
- Withstands chemical corrosion
- Easily formed, molded, worked
- Withstands weathering

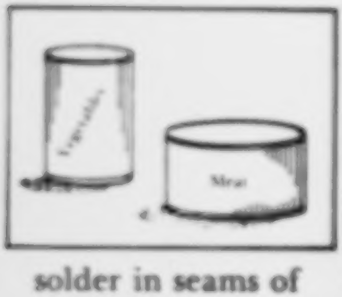
Uses:



cookware with soldered seams



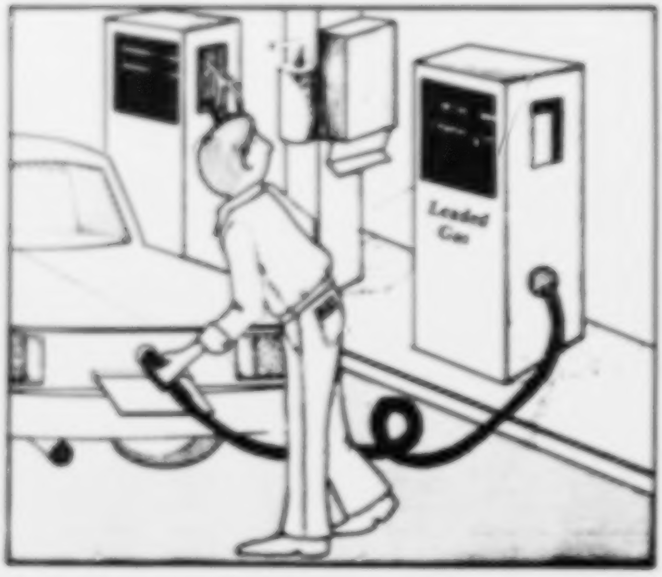
old-time water conduits



solder in seams of food containers

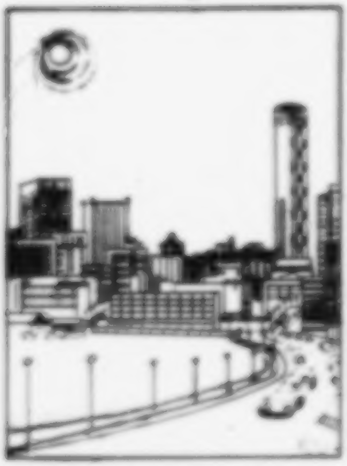
Of principal interest to air pollution control personnel . . .

- lead emissions from autos using fuel that contains lead
- lead's toxic effects on people

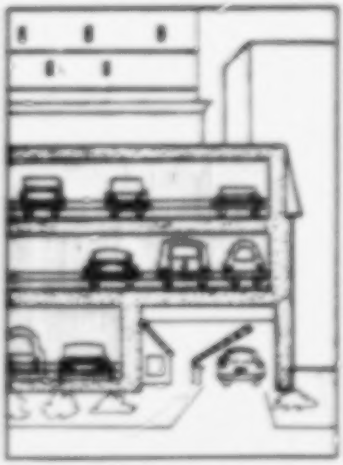


Lead contained in gasoline accounts for more than ¾ of all lead emissions in the U.S.

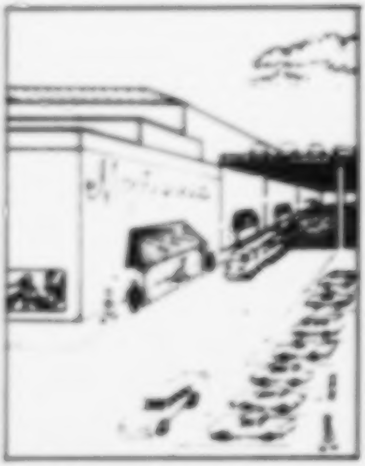
Largest Concentration of Lead Emissions



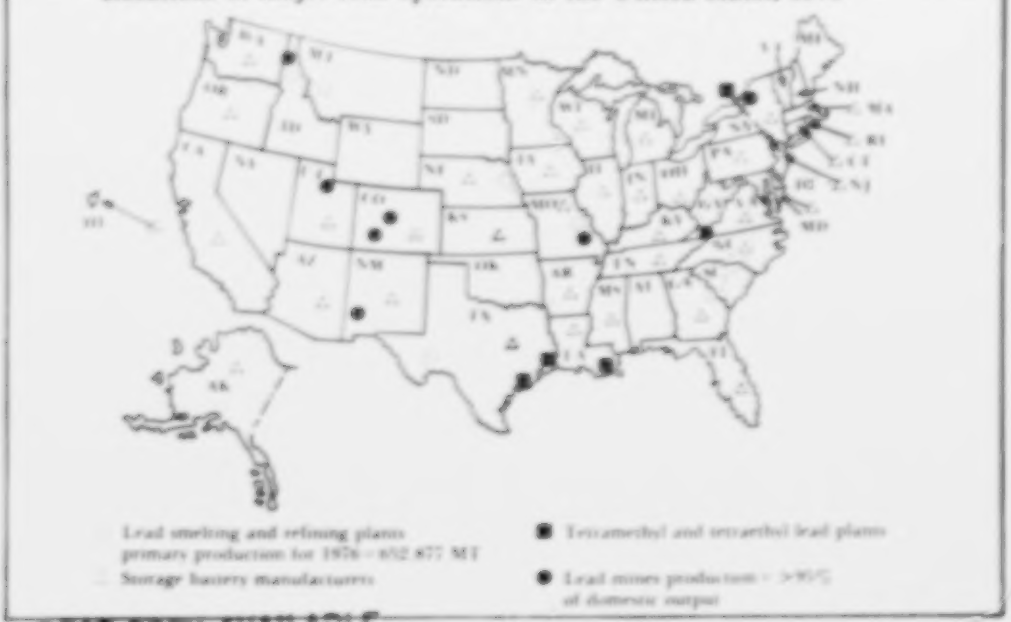
large metropolitan areas



parking garages



shopping areas



Locations of major lead operations in the United States, 1976

Lead smelting and refining plants primary production for 1976 = 652 877 MT
Storage battery manufacturers
■ Tetramethyl and tetraethyl lead plants
● Lead mines production = >95% of domestic output

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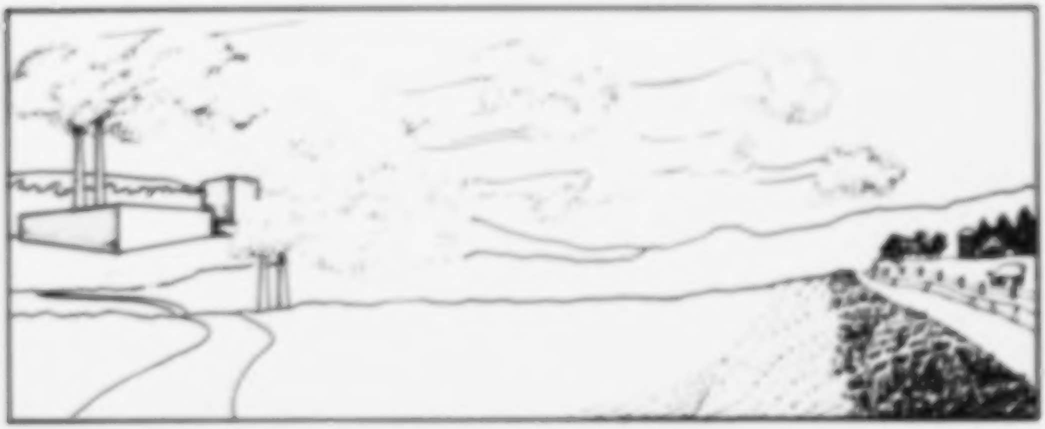
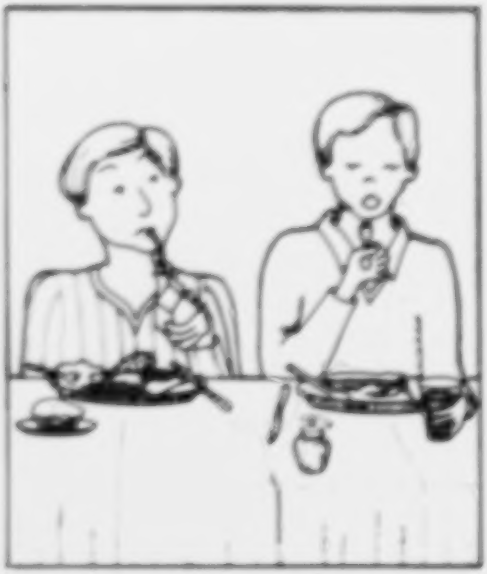
Lead emissions may be carried for miles downwind from the source.

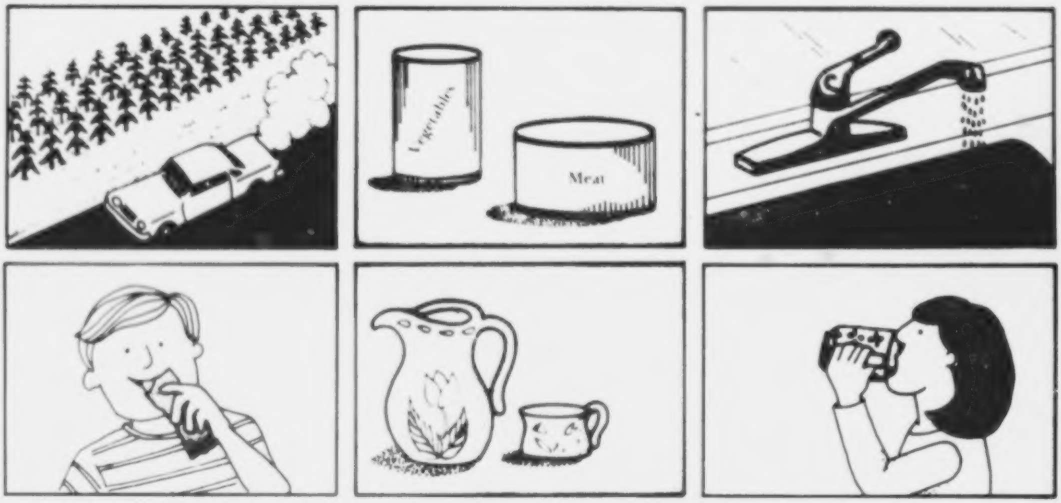


The **total body burden** is the sum of all lead in the system. Lead is **not** removed quickly from the body.

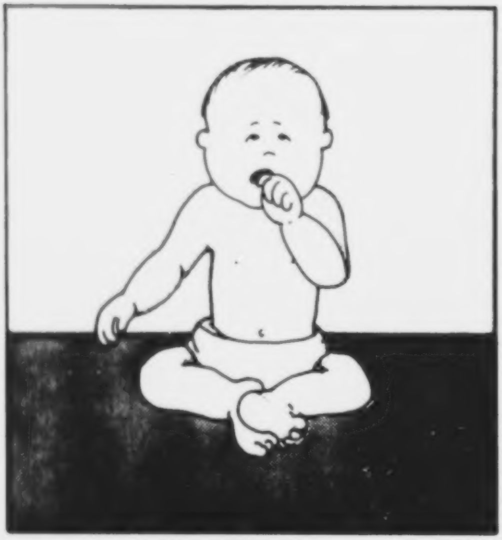


Eating and drinking are the principal mechanisms for lead entry into the body—but we also inhale lead particles.

Possible Sources of Ingested Lead



Children will ingest substantial quantities of lead by putting their hands in their mouths after handling dirty objects.



Children have a greater sensitivity to lead than do adults because they have

- greater lead intake on a per-unit-body-weight basis
- greater net respiratory intake and greater absorption and retention in digestive system
- rapid growth – reducing margin of safety against stress
- certain incompletely developed defense mechanisms
- different partitioning of lead in bones

Expectant mothers and their unborn and newborn children are an unusually sensitive population to lead pollution ⇩

- miscarriages
- stillbirths
- deaths of the newborn

Formation of red blood cells is impaired by intake of environmental lead which may lead to:

- anemia
- irreversible brain damage
- death

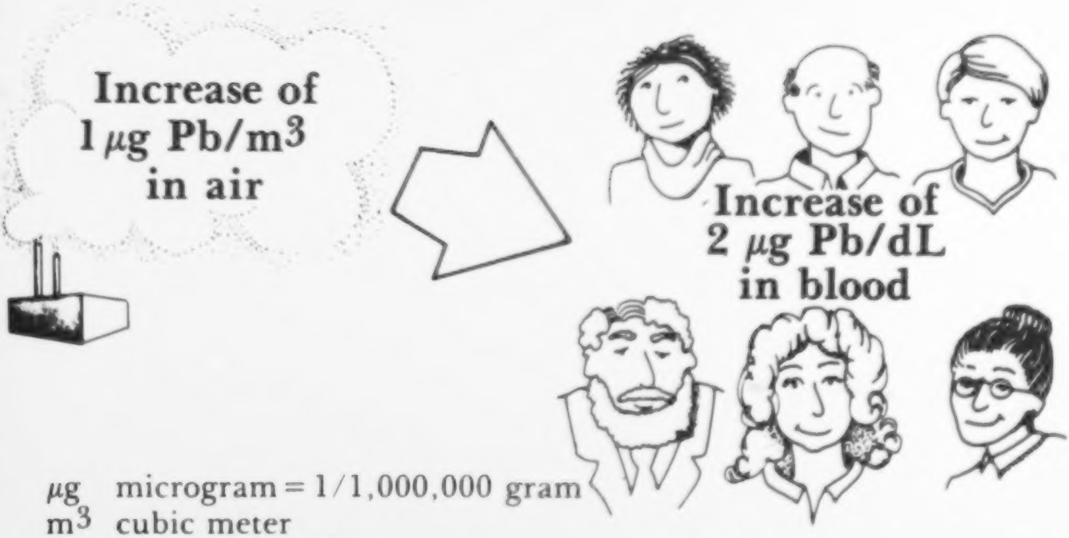
Types of Effects of Lead Noted in Studies of Laboratory Animals

- **gametotoxic** — effect on cell division
- **embryotoxic** — effect on embryo
- **carcinogenic** — effect on cell growth & character
- **teratogenic** — effect on embryo — producing abnormal species

Blood levels of 80 to 100 micrograms lead per deciliter* may result in

- central nervous system defects
- behavioral defects

*deciliter = 1/10 liter (approx. 1/10 quart)


Increase of
1 µg Pb/m^3
in air
Increase of
2 µg Pb/dL
in blood

µg	microgram = 1/1,000,000 gram
m^3	cubic meter
dL	deciliter = 1/10 liter
Pb	lead

Animals which feed on plants near highways with heavy traffic show lead poisoning symptoms.

There seems to be no detrimental effect of lead on materials.

"Lead is not conclusively known to have any biological effect on man that can be considered beneficial"—EPA Lead Criteria Document

Lesson IX
Questions

1. Which of the following are the two major concerns that air pollution control personnel have about lead?
   - a. lead emissions from autos using fuel that contains lead
   - b. the effect of lead on exterior coatings
   - c. the toxicity of lead
   - d. the effect of lead on metal structures
2. Which of the following describes how lead emissions may be carried from urban sources to rural areas?
   - a. by streams
   - b. by wind currents
   - c. by passing motorists
   - d. by animals
   - e. all of the above
3. Which of the following best describes the rate at which lead is removed from the body?
   - a. very slowly
   - b. very quickly
   - c. not at all
   - d. all at once
4. How does most lead enter our bodies?
   - a. through breathing
   - b. through eating and drinking
   - c. through the skin
   - d. all of the above
   - d. none of the above
5. Which of the following is most adversely affected by lead?
   - a. our blood
   - b. our skin
   - c. our lungs
   - d. all of the above
   - e. none of the above
6. Describe the effect of lead upon materials.

After checking your responses, review any material that you are not sure of, and then take the Unit Test.

Lesson IX
Answers

1. **a, c.** **lead emissions from autos using fuel that contains lead, and the toxicity of lead**
2. **b. by wind currents**
3. **a. very slowly**
4. **b. through eating and drinking**
5. **a. our blood**
6. **Lead has no detrimental effect upon materials.**

The Effects of Air Pollution

Unit Test

1. A(n)__________is a measurable or perceivable detrimental change in a receptor, presumed to result from the interaction of the receptor with an air pollutant. The receptor may be a human, plant, animal, microbe, or other matter.
2. Choose the phrase that best completes the sentence. Ambient air is:
   - a. the air in the top part of a stack.
   - b. the air inside a smelter.
   - c. the air all around us.
   - d. the air contained in water.
3. True or False: As pertains to air pollution control, primary standards are set to protect public health, and secondary standards are set to protect public welfare.
4. Which of the following are *criteria* pollutants?
   - a. ozone
   - b. iron
   - c. carbon monoxide
   - d. sulfur dioxide
   - e. magnesium
   - f. lead
   - g. plutonium
   - h. nitrogen dioxide
   - i. hydrocarbons
   - j. suspended particulate matter
5. True or False: A scientist studying effects of air pollution is often trying to prove a *causal* relationship.
6. Which three of the following are major types of studies of the effects of air pollution?
   - a. case studies
   - b. pollutinogenic studies
   - c. inverse relational studies
   - d. laboratory studies
   - e. air correlation studies
   - f. general field studies
7. In the field of air pollution, what is meant by a "synergistic effect"?
8. Name the type of substances that are produced when sulfur dioxide combines with moisture.
9. Arrange the following in order of toxicity - from most toxic to least toxic.
   SO_2 combined with particulate matter
   SO_2 alone
   SO_2 combined with moisture
10. Describe what is meant by "dose" as it pertains to air pollution.
11. Which are the two major factors that may influence the effect of suspended particulate matter?
    - a. color of particles
    - b. opacity of particles
    - c. size of particles
    - d. number of particles

CONTINUED ON NEXT PAGE

12. Match each of the three respiratory regions listed with its particle removal system.
    - i. upper respiratory system
    - ii. tracheobronchial region
    - iii. lower respiratory region

    - a. filtration and preconditioning system
    - b. bronchioclarification system
    - c. mucus filtration and elimination system
    - d. pulmonary clearing mechanism
    - e. impaction and mucus-transport system
13. Choose the term that best completes the sentence. Cilia are:
    - a. air sacs.
    - b. small bronchial tubes.
    - c. blood cells.
    - d. small hair-like cells.
    - e. small pollutants.
    - f. bacteria-like microbes.
14. Which of the following are ways that suspended particulate matter affects visible light?
    - a. reflects it
    - b. scatters it
    - c. bends it
    - d. changes its shape
    - e. absorbs it
    - f. changes its color
15. Describe how carbon monoxide affects gas exchange in our blood.
16. Which of the following diseases are most likely to be aggravated by carbon monoxide?
    - a. circulatory diseases
    - b. mononucleosis
    - c. eczema
    - d. heart diseases
    - e. peridontal diseases
    - f. gastrointestinal infections
17. Which is most toxic to humans, nitric oxide or nitrogen dioxide?
18. Which of the following are effects of exposure to oxides of nitrogen?
    - a. metal can be damaged
    - b. fabrics loose strength
    - c. dyes change colors
    - d. only a and b
    - e. a, b, and c
19. Damage directly to plants and materials by VOCs and hydrocarbons:
    - a. is maximum in the winter.
    - b. is a problem only for synthetic materials.
    - c. is not considered a problem.
    - d. results in $10 million in losses each year.
20. Which type of hydrocarbons are most biologically and biochemically active?
21. Describe how hydrocarbons can get from urban sources to rural areas.
22. What is the most beneficial effect of the ozone that is found in the stratosphere?
23. Which types of activity found in the lungs are adversely affected by exposure to ozone?
    - a. enzyme
    - b. chemical
    - c. cellular
    - d. all of the above
24. Choose the word that best completes the sentence.

    Ozone probably causes __________ (more, less) plant damage in the United States than any other air pollutant.

25. True or False: Exterior coatings and finishes (paints, etc.) often deteriorate when exposed to ozone.
26. Describe how lead emissions may be carried from urban sources to rural areas.
27. Is lead removed from the body very slowly or very quickly?
28. How does most lead enter our bodies?
    - a. through breathing
    - b. through eating and drinking
    - c. through the skin
    - d. all of the above
    - e. none of the above
29. Which of the following is most adversely affected by lead?

a. our blood	d. our teeth
b. our skin	e. our hair
c. our lungs	f. our eyes

30. True or False: Lead seems to have no detrimental effect upon materials.

Unit Test
Answers

1. effect
2. c. the air all around us
3. True
4. a. ozone
   c. carbon monoxide
   d. sulfur dioxide
   f. lead
   h. nitrogen dioxide
   j. suspended particulate matter

5. True
6. a. case studies
   d. laboratory studies
   f. general field studies
7. The combined effect of pollutants is *worse* than the sum of the effects of the individual pollutants.
8. Acids
9. SO_2 combined with moisture
   SO_2 combined with particulate matter
   SO_2 alone
10. The concentration of the pollutant and the length of exposure to the pollutant.
11. c. size of particles
    d. number of particles

12. i. a. filtration and preconditioning system
    ii. c. impaction and mucus-transport system
    iii. d. pulmonary clearing mechanism
13. d. small hair-like cells
14. a. reflects it
    b. scatters it
    c. absorbs it
15. Carbon monoxide displaces oxygen in the red blood cells, thus depriving the body of oxygen.
16. a. circulatory diseases
    d. heart diseases
17. Nitrogen dioxide
18. e. a, b, and c
19. c. is not considered a problem.
20. Aromatic hydrocarbons
21. They are carried by wind currents.
22. It screens out harmful ultraviolet rays coming from the sun.
23. d. all of the above
24. more
25. True
26. They can be carried by wind currents.
27. Very slowly
28. b. through eating and drinking
29. a. our blood
30. True

PART III
AIR POLLUTION WORKBOOK

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A. THE EARTH'S ATMOSPHERE

The earth is surrounded by a blanket of air that is approximately 500 miles thick. Gravity pulls approximately $5\frac{3}{4}$ quadrillion tons of air toward the earth. The result is that about one-half of the air is pulled within 3½ miles of the earth and more than 99 percent of the atmosphere lies within 25 miles.

Air is invisible, odorless, and tasteless. It is a mixture of nitrogen (78.1%), oxygen (20.9%), varying amounts of water vapor, a small amount of carbon dioxide (0.03%), and other trace gases. At the bottom of this sea of air lives man. He is totally dependent on this air which he breathes in about 22,000 times a day. Man could not survive longer than several minutes if this sea of air were removed.

However, man also uses this precious resource to discard much of his wastes or contaminants. If these contaminants have adverse effects such as causing poor health, reducing visibility, or damaging plants or materials, these wastes are called pollutants. Air pollution is defined as the presence of one or more contaminants put there by the activities of man in quantities which may injure human, animal, or plant life or property; or which may interfere with the enjoyment of life or property. When man pollutes his atmosphere, he may do more than damage his immediate environment. Some air pollutants may travel hundreds of miles from their original source and interact with other pollutants along the way. The atmosphere is not capable of immediately dispersing any and all pollutants released into it. Only with time, may pollutants become more or less uniformly distributed.

Activities

1. Draw a diagram indicating the different layers of the earth's atmosphere and label them.
2. About 95% of the "air" is concentrated in the twelve miles above the earth. Man can use only a fraction of this because much of the air at higher altitudes is too thin to breathe. On your diagram, indicate the portion of the atmosphere that has "breathable air."
3. Place a glass upside down over a pan of water. Push the glass down into the water. Does the water fill the glass? If not, why not?
4. Living things require oxygen in varying amounts according to their physical activity, rate of metabolism, and body size. Discuss the importance of air to our lives. a) Using a watch, have the class compute the average number of breaths in an hour and in a day. b) Compare the length of time a person can live without air, food, and water.

5. The atmosphere is limited, and our supply of air is not inexhaustible. We are polluting the air daily by adding substances which are not natural constituents and increasing the amounts of natural substances, possibly changing the ecological balance. Compare the earth's limited atmosphere with the sealed atmosphere in a spaceship.

6. Discuss the definition of air pollution. List examples of its injurious effects and ways in which it may interfere with the enjoyment of life or property.

7. Nature may also pollute the air by natural events such as volcanic eruptions, forest fires, and dust storms. Report on a few of these events and their effects on the air.

8. Air pollution problems can be traced back many hundreds of years. Research and discuss some of these historical episodes. Also, determine if the quality of the air in your region has become better or worse.

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B. METEOROLOGY AND ITS RELATION TO AIR POLLUTION

Early in man's history, nature could take care of her own pollution whenever a volcano erupted or a forest burned. There were sufficient winds, rain, and air currents to disperse the pollutants. However, as man increased the volume of his pollutants, these natural air cleaners could not keep up and pollution increased further.

Several factors play an important role in determining the seriousness of an air pollution problem. 1) Types and quantities of pollutants produced by community activities; 2) Topography; 3) Weather conditions—such as wind speed and direction, sunlight, precipitation, clouds, fog, relative humidity, temperature, the decrease or increase in air temperature with height, and the background pollution level of incoming air masses. Have you ever noticed that the air may look polluted one day and clear the next—even though the same amount of pollution is being emitted? Breezy conditions or precipitation will help disperse pollutants; however, weak winds and stable conditions may permit even small quantities of pollutants to accumulate.

Fair weather (high pressure systems) and storms (low pressure systems) usually move in a general west to east pattern at about 20 to 30 miles per hour. At these speeds, much of the air pollutant is diluted and blown away. However, when a high pressure system becomes stationary, there is very little wind to blow away the pollutant.

Pollutants also increase when an inversion exists. Normally, air temperature decreases as the altitude increases. However, during an inversion, the air temperature increases with altitude. Pollutants emitted under normal conditions are warmer and less dense than the surrounding air; as a result, they rise and are dispersed. In an inversion situation, the pollutants will rise only to the point where they reach air which is warmer than itself. When this layer of warm air is low, the pollutants accumulate near the ground because they cannot penetrate the warmer air.

There is one easily recognizable type of inversion, called a nocturnal inversion, which can be seen on most calm, clear mornings. This sort of inversion is formed during the night when the ground loses heat faster than the air, becomes cooler than the air above it, and chills the air immediately in contact with it. On mornings when these inversions occur, there is usually dew, frost, or ground fog. The next time one occurs, look at a smoke stack or the exhaust pipe from a car. Notice that the pollutants linger rather than disperse. This situation usually disappears by mid-morning as the sun warms the ground and destroys the inversion.

Topography can have an important influence on the wind and therefore on the dispersion or accumulation of pollutants. Consider a city in a valley. The cool air that is formed on the hillsides at night flows to the bottom of the valley by morning. As a result, the air near the ground is colder than the air above, and an inversion occurs. There are some topographic features that have a variable effect on air pollution. Mountaintop areas generally have good wind conditions and coastal locations often experience sea or lake breezes. The strong winds on a mountaintop produce conditions which disperse pollutants while the complex nature of the seabreeze may result in higher concentrations of pollutants.

Activities

1. Refer to a book on meteorology and explain how the air movements around the earth determine our weather.
2. Draw a diagram to illustrate temperature change with altitude in normal conditions. Also, illustrate what occurs during an inversion.
3. On a cold day, open a window. You will be able to feel the cold air coming in and falling to the floor. This occurs because cold air is denser and heavier than warm air. Any pollutants in the cold air would be trapped near the floor with a layer of warm air above them. What does this demonstrate?
4. Explain why cities in valleys are susceptible to poor air quality.
5. Discuss why an inversion may produce high concentrations of air pollutants.
6. Use weather reports and a map to show how polluted air might travel in your area.
7. Discuss how topography might influence the weather in your area. Does this influence help to increase or decrease your pollution?
8. For one month, keep a diary of the air quality in your area. When the newspaper or radio announces that the air is unhealthy or unsatisfactory, record this and:
    a) note the weather conditions (cloudy, fair, rain, etc.)
    b) note the average wind speed
    c) look at the daily weather map in your newspaper for several consecutive days. Determine if a high pressure system is remaining stationary. Record this information.
9. With each additional day that a high pressure system remains stationary, the concentrations of pollutants may increase. If this situation continues for a few days, the air may produce adverse effects. Every state is required to have a law to prevent such a situation. These laws define three stages: air pollution alerts, air pollution warnings, and air pollution emergencies. Determine how your state defines these stages, what control measures would occur at each stage, and whether your state has ever reached any of these stages.

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Experiment B:1 INVERSION PRINCIPLE

Objective: To determine the principle of an inversion.

Materials: Four medium size jars of the same size with lids; tongs; refrigerator; radiator or pan of hot water; 2 pieces of paper—2" X 4"; matches.

Procedure:

1. Place two jars in the refrigerator (or outdoors on a cold day) for 10 minutes with their lids on loosely.
2. Remove the lids from the remaining two jars and place them on a radiator or in a pan of hot water until the jars are slightly warm to touch (but not too hot to touch).
3. Remove the jars from the heat source and replace the lids.
4. Fold a piece of paper into a ¼" X 4" strip. Hold it with the tongs and light it with a match.
5. Drop the burning paper into one of the jars containing warm air. Then place the lid (but do not tighten) over the jar so that it becomes smoke-filled.
6. When the jar is filled with smoke, remove the lid and invert one of the cold jars over it. Do it carefully to avoid disturbing air movement.
7. Allow the jars to remain together for several minutes without disturbing them.
8. Observe if the smoke rises into the cold air.
9. Repeat step 4.
10. Drop the burning paper into the remaining jar containing cold air. Then, place the lid (without tightening) over the jar so that it becomes smoke-filled.
11. When the jar is filled with smoke, quickly remove the lid and invert the remaining warm jar over it. Do it carefully.
12. Allow the jars to remain together for several minutes without disturbing them. Observe if the smoke rises into the warm air.

Results: Record the results.

Discussion: Did the smoke behave differently in the two bottles? Explain.

C. TYPES OF AIR POLLUTANTS: PARTICULATE, GAS, AND LIQUID

Man-made air pollutants are emitted directly into the atmosphere (primary pollutants) or are formed in the atmosphere by chemical reactions involving primary pollutants (secondary pollutants). During its chemical transformation into a secondary pollutant, a chemical may change from a harmless state into one which may be harmful at high concentrations, e.g. nitric oxide to nitrogen dioxide. Air pollutants also are produced by nature—e.g. pollens, spores, bacteria, soil dust, sea spray, volcano and forest fire emissions.

Pollutants in the air are usually divided into two major groups: particulates and gases, but recently a third form of pollution has been recognized that is in a liquid state.

1. Particulates

Particulates are suspensions of fine liquid or solid substances in the air. There are two other commonly used terms—particles and aerosols. Particles refer only to solid substances whereas aerosols may be either liquid or solid substances suspended in the air. Some examples of particulates are: soot, soil particles, oily droplets, dusts, acid mists, smoke, fumes, and fog. Particulates can be produced from incomplete burning, grinding, spraying, sawing, drilling, etc.

In the atmosphere, particulates occur in may sizes and shapes. Usually they are classified into fine particulates, those with a diameter less than 2.5 microns (which is approximately $\frac{1}{100,000}$ of an inch), and coarse particulates, those greater than 2.5 microns. The fine particulates are more important, because they can be inhaled by man and animals and enter the lung. Also, fine particulates (0.3-1.0 microns) are responsible for reducing visibility. Fine particulates are formed primarily from incomplete combustion and the chemical reactions of primary pollutants in the atmosphere. They are light in weight and can exist in the atmosphere for days.

Coarse particulates are formed primarily from windblown soil dust, grinding processes, and seaspray. They are generally less of a problem than fine particulates, because the pull of gravity causes them to fall out of the air—usually within hours. However, those coarse particles which are between 2.5 to 15 microns in diameter may be important from a health standpoint to people with respiratory problems who often breathe through their mouths. For people who breathe normally through their noses, these particles would not be a problem since they are removed in the nasal passages.

Particulates reduce visibility by scattering and absorbing light. This results in a haze in many urban areas which causes sunlight to be reduced. Also, light scattering due to particulates can produce the red sky which is sometimes seen at sunrise and sunset.

2. Gases

A second group of air pollutants is composed of gases. While only a relatively small percentage of the gases in the atmosphere are pollutants, they play an important role because of their harmful or unpleasant effects. Some gaseous pollutants are released into the atmosphere during combustion processes, some are released by the process of vaporization (the change of a liquid to a gaseous state), and some are formed from chemical reactions in the atmosphere.

The principle gaseous pollutants in the atmosphere can be categorized as: carbon-containing gases, sulfur-containing gases, nitrogen-containing gases and ozone.

(a) Carbon-containing gases which are pollutants include carbon monoxide (CO), hydrocarbons, and oxygenated hydrocarbons. Carbon monoxide is a toxic, colorless, odorless gas produced from the incomplete combustion of fuels. Hydrocarbons are a class of compounds formed from incomplete combustion or evaporation of gasoline, fuel oil, or solvents. They are composed of carbon and hydrogen in various proportions. Oxygenated hydrocarbons are compounds which contain oxygen in addition to the carbon and hydrogen. Some of these are formed by combustion while some are secondary pollutants formed from chemical reactions between hydrocarbons and oxygen in the presence of sunlight. Many of the hydrocarbons and oxygenated hydrocarbons are carcinogenic (cancer-causing). An example of a carcinogenic hydrocarbon is benzene.

(b) The principle sulfur-containing pollutant gas is sulfur dioxide (SO_2). When fuels containing sulfur are burned, the sulfur joins with the oxygen of the air and produces sulfur dioxide which in high concentrations is a pungent, irritating gas. Sulfur dioxide reacts with other materials in the atmosphere to form sulfuric acid particles and sulfate salt particles. Sulfuric acid is a dangerous and highly corrosive pollutant. In the past, there have been periods of air stagnation which have allowed sulfur dioxide and sulfuric acid to accumulate to high concentrations producing serious pulmonary problems. Such episodes occurred in Donora, Pennsylvania in 1948 and in London, England in 1952 and other years.

Other sulfur-containing air pollutants are mercaptans (C, S, and H compounds) and hydrogen sulfide (H_2S) which may be produced by decomposing organic matter. Mercaptans and hydrogen sulfide are not common pollutants, but when they are present, they can be distinguished by their respective gas-like or rotten egg-like odors.

(c) Nitrogen-containing gases which are pollutants include nitric oxide and nitrogen dioxide. Nitric oxide is a colorless, relatively harmless product of burning fuels at high temperatures, but it can react with oxygen atoms to form nitrogen dioxide. This reaction occurs especially in the presence of photochemical smog-producing conditions. Nitrogen dioxide has a sweet-pungent odor, is yellowish-brown in color, and in high concentrations can appear brown. The two largest source categories for nitrogen oxides are stationary fuel combustion (industry, power generation, and space heating combustion) and motor vehicle emissions. Nitrogen oxides are a major component required for the formation of photochemical smog and acid rain.

In addition to nitric oxide and nitrogen dioxide, there are some organic nitrogen compounds (carbon-hydrogen-nitrogen compounds). An example is peroxyacetyl nitrate commonly known as PAN which is formed by chemical reactions in photochemical smog. PAN is a phytotoxicant (i.e. it is harmful to plants).

(d) Ozone is a gas composed of three atoms of oxygen, whereas the oxygen which we require for breathing contains two atoms of oxygen. Ozone is colorless with a distinctive "fresh air" smell experienced frequently during thunderstorms. Ozone occurs in the atmosphere naturally but also can be formed by chemical reactions involving nitrogen oxides and hydrocarbons in the presence of sunlight near the earth's surface. Chemical reactions which involve sunlight are called "photochemical" reactions.

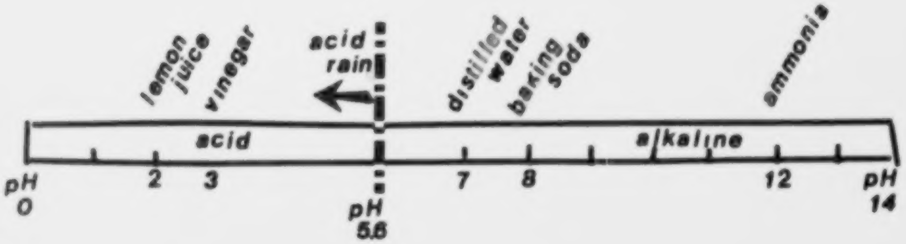
There are three sources of natural ozone. The major one is in the stratosphere where the production of ozone occurs by the photochemical reaction of ultraviolet light with oxygen. Stratospheric ozone is frequently brought down near the earth's surface by air currents and can constitute a large amount of the ozone observed at ground level. Ozone is also produced by lightning, but this is a minor source. The third way that natural ozone is produced is by photochemical reactions involving nitrogen oxides and naturally-emitted hydrocarbons from vegetation. Examples of natural hydrocarbons are terpene compounds which are produced by and have the distinctive odor associated with conifer trees. On the average, ozone produced naturally accounts for more than half of the measured ozone concentrations.

Ozone is a very important constituent of photochemical smog. During the summer months when sunlight is the strongest, ozone produced in photochemical smog can be significantly greater than that produced by natural sources.

3. Liquids

Acid rain, or acid precipitation, has recently received much attention because of the severe ecological impact it may have on widespread areas of the environment. As a result of the combustion of tremendous quantities of fossil fuel such as coal and oil, the United States annually discharges approximately 50 million metric tons of sulfur and nitrogen oxides into the air. Through a series of complex chemical reactions these pollutants can be converted to acids which may return to earth as components of either rain or snow.

Acidity is measured in pH units. The pH symbol represents the concentration of electrically-charged hydrogen ions in solution. The scale below shows the pH of some common compounds.



Rain falling through a clean atmosphere has a pH of 5.6 to 7.0 pH units. Acid rain has a pH lower than 5.6. In general, the lower the pH, the more polluted and more corrosive the rain becomes. Snow, as well as rain, may contain acid components.

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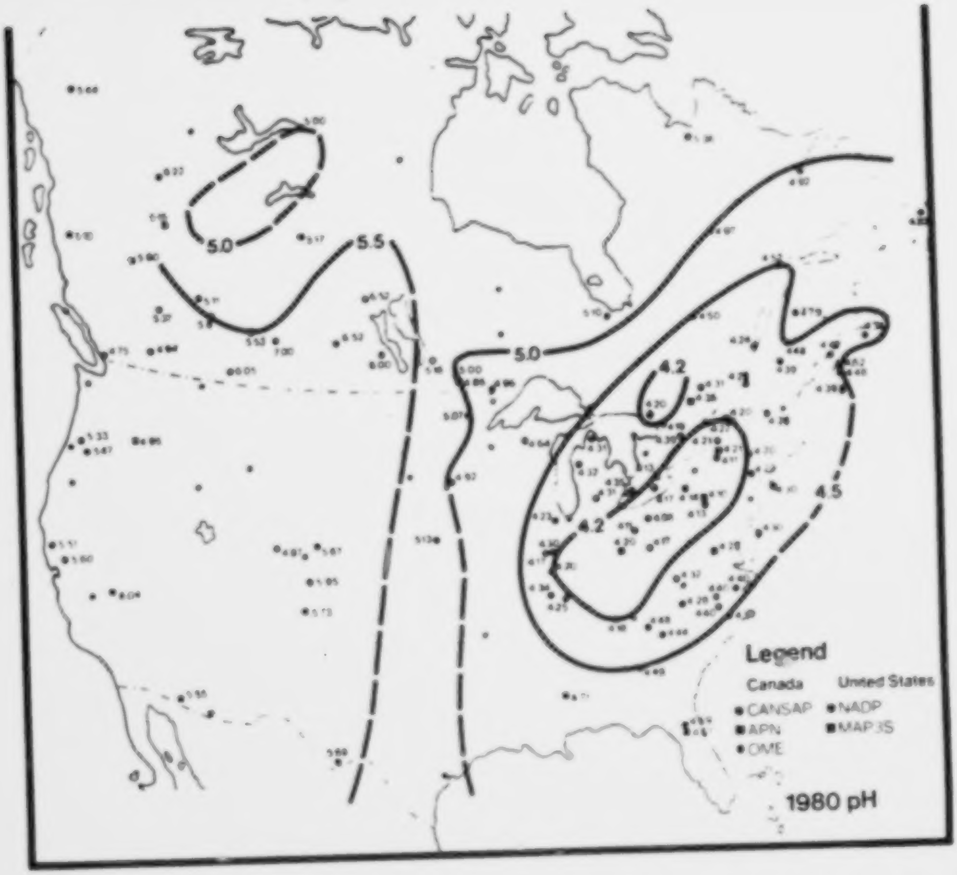

Spatial variation of precipitation-amount-weighted mean pH in North America in 1980 compiled from Canadian (CANSAP, APN) and American (NADP, MAP3S) networks.

Hundreds of lakes in North America and Scandinavia have become so acidic that they can no longer support aquatic life. More than 90 lakes in the Adirondacks in New York State are fishless because acidic conditions have inhibited reproduction.

Acid rain is contributing to the destruction of stone monuments throughout the world. Adverse effects on agriculture and forestry have been suspected but not documented.

Activities

1. List all the evidence you find that air around your school, home, and neighborhood contains pollutants (dust on cars, smokestacks' emissions, etc.).

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2. Changes in the quality of our air are not always evident, because the comparisons may involve differences of only a few parts per million. Also, some pollutants such as carbon monoxide are invisible and odorless. We depend upon measurements of pollutants taken by local, state, and federal pollution control agencies to determine if our air quality is acceptable. Determine if your local or state pollution control agency publishes or broadcasts a Pollutant Standards Index (PSI). This is usually a daily report issued to advise the public of the quality of the air. If this is available in your area, keep a record of the PSI, visibility, and weather conditions for one month. Determine if there are any relationships among these data.

3. Prior to the early 1970's, many smoke stacks emitted black or gray smoke. The amount of pollution emitted from these stacks often was measured by a Ringelmann chart. Today, the majority of stacks utilize air pollution controls which reduce the quantities of particles; however, a few still emit various shades of gray to black smoke.

   A Ringelmann Smoke Chart (U.S. Bureau of Mines, Publications Distribution Branch, 4800 Forbes Avenue, Pittsburg, PA 15213) consists of a series of grids composed of black lines ruled on a white background. When the chart is held at arm's length, the grids appear as graduated shades of gray that vary between all white and all black. Each shade of gray represents a certain smoke density. It is possible to estimate the density of the smoke by matching as closely as possible the shades of smoke to the shades of gray on the Ringelmann chart. The lightest shade of gray represents 20% density; second grayest, 40%; third grayest, 60%; and darkest gray, 80%.

   Use a Ringelmann chart that is placed 50 feet from you to estimate the density of smoke coming from a smoke stack or chimney at half-minute intervals for 10 minutes. This should be done preferably with the sun at your back and the wind blowing across the stack at right angles to you.

4. If you have access to a pH meter, measure the pH of some more common household compounds such as lemon juice, vinegar, and baking soda. Also collect several rain samples in clean plastic bottles and test the pH of the rain.

5. Not all air pollution is a consequence of man's activities. Natural air pollutants, e.g. pollen and spores, are present in our environment. When vegetation is active (e.g. spring, summer, and fall in most areas), cover several clean microscope slides with petroleum jelly and suspend them with pinch-type clothespins from fencepost stakes, clothesline, etc. Place the slides in areas free from obstructions for a 24-hour period without precipitation. Using a microscope, examine the slides for the presence of pollens and spores.

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Experiment C:1 ARE PARTICULATES PRESENT IN YOUR ENVIRONMENT?

Objective: To demonstrate the presence of particulates in your environment.

PART A

Materials: Projector or flashlight.

Procedure: Darken the room and observe the beam of light from a source such as a flashlight or a projector.

Results: Record the results.

Discussion: Particulates are present in the air. Particles which you saw have not settled to the ground, but are still in suspension. What eventually happens to these particles? Do they fall to the ground? Explain.

PART B

Materials: Microscope slides; paper labels; petroleum jelly; microscope or magnifying glass.

Procedure:

1. Select several sites in your community which will provide contrasts and comparisons in air quality. The following should be considered: topography--valleys, mountains, waterways, etc.; traffic flow patterns, residential areas; sites of industrial plants, incinerators, and power plants; and prevailing wind patterns. Two sites which also should be included are inside the classroom and outside the school.
2. At each site which has been selected, place three of the glass slides.
3. Near one edge of each slide, attach a paper label. Then, evenly cover one side of each slide with a layer of petroleum jelly.
4. For each day of the experiment, a record of the wind direction and rainfall should be kept.
5. One slide should be collected from each site at Day 1, Day 3, and Day 7. (Day 0 being the day the slides were placed in position.) Label each slide for date and location. If precipitation occurs during the seven days, this will wash away the petroleum jelly. Therefore, it may be necessary to repeat the experiment until there have been seven consecutive rainless days.
6. Examine each set of slides as soon as possible after collection. Use a microscope or place the slides on a piece of white paper and study each one under a bright light using a magnifying glass.

7. After each set has been examined, cover with a clean slide and store in a safe place.
8. After this procedure has been accomplished for the slides of Day 1, Day 3, and Day 7, compare the slides exposed for 1 day with the slides exposed for 3 and 7 days.

Results: Make a chart comparing the color, size, and amounts of particulates on each slide. Note the location, wind direction during the time it was exposed, and the length of time exposed.

Discussion: Discuss the results shown on the chart which you have prepared.

Experiment C:2 HOW MUCH DUST FALLS OUT OF THE AIR?

Introduction: Particulates that settle out of the air are known as dustfall. Dustfall can be used as a rough indicator of air quality with respect to coarse particulate matter. Dustfall is influenced by particulate emission rates, topography, dryness of soil, amount of sand or salt recently applied to nearby roads, wind speed and direction, precipitation, etc.

Objective: To determine the amount of dustfall in a given month over a small area.

Materials: Wide mouth gallon jars or plastic buckets; distilled water; isopropyl alcohol (only needed in winter as an anti-freeze); pyrex beaker; laboratory scale; rubber policeman; small mesh screen; evaporating dish; burner or hot plate; ruler.

Procedure:

1. Fill the gallon jars or plastic buckets one-third full of distilled water. Add about 8 ounces of isopropyl (rubbing) alcohol if temperatures will be below freezing in the next 30 days.
2. Select a few sampling sites at different locations. Proper site selection is important. Each sampling site should have a free exposure so that the sampling jar or bucket collects the sample by gravity settling only. It should be away from splatter from trees and buildings. A low flat roof would be an ideal location; however, accessibility and freedom from tampering should be major considerations. The jars or pails should be firmly placed to prevent them from tipping.
3. The jars or buckets should be placed at their sites and checked regularly to insure that the container does not go dry or overflow in periods of rain. Water should be maintained in the container to prevent loss of the dustfall by wind action.
4. After 30 days, remove the extraneous matter (such as large insects, leaves, etc.) by passing the contents of the jar or bucket through a mesh screen into a Pyrex beaker of suitable size.
5. Discard the residue on the screen, but add to the beaker any sludge that was on the bottom of the jar or bucket.
6. Using a burner or hot plate, slowly evaporate the liquid in the beaker to a small volume. Transfer the residual liquid and solids in the beaker to a preweighed evaporating dish. Use a rubber policeman to insure that all the contents have been transferred.
7. Using a low flame, heat the evaporating dish until the sample is dry.

8. Weigh the evaporating dish plus residue after the dish has cooled and can be touched

Results:

1. Determine the weight of the dustfall collected in one month by subtracting the weight of the preweighed evaporating dish from that of the dish plus residue.
2. Use a ruler to measure the opening of the jar or bucket and then calculate its surface area using the formula:

   $A = \frac{\pi d^2}{4}$, where d is diameter. (The size of the opening will be used as the diameter.)
3. Now that the weight of the dustfall that fell into the jar in 30 days is known, perform the following calculations:

$$\text{dustfall in lbs/1000 ft}^2 = \frac{\text{gms dustfall collected in 1 month}}{\text{area of bucket in square inches}} \times \frac{1\text{ lb}}{454\text{ gms}} \times \frac{144\text{ in}^2}{1\text{ ft}^2} \times 1000\text{ ft}^2$$

This is a significant figure, since this is the amount of dust that falls on the "average" house in one month.

Also, calculate the dustfall in tons per square mile per month:

$$\text{dustfall in tons/mi}^2\text{/month} = \frac{\text{gms dustfall collected in 1 month}}{\text{area of bucket in square inches}} \times \frac{1\text{ lb}}{454\text{ gms}} \times \frac{1\text{ ton}}{2000\text{ lb}} \times \frac{144\text{ in}^2}{1\text{ ft}^2} \times \frac{27{,}878{,}400\text{ ft}^2}{1\text{ mi}^2}$$

Discussion: If more than one sampling site was used, compare the results of the various sites.

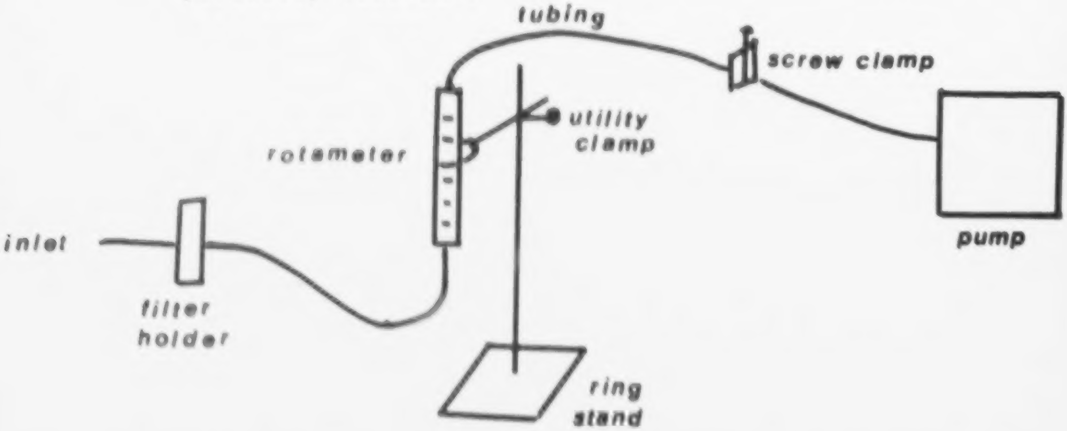
Experiment C:3 DO THE PARTICULATES IN OUR ENVIRONMENT REMAIN CONSTANT?

Objective: To determine whether the concentration of particulates in our environment remains constant.

Materials: Forty-seven mm diameter white glass fiber or paper filter paper; 47 mm filter holder; vacuum pump capable of pulling 20 liters per minute; a flowmeter (rotameter) with a range from 0—20 liters per minute; thick-walled Tygon tubing; screw clamp; Petri dishes; ring stand assembly; and a utility or buret clamp.

Procedure:

1. Place a piece of filter paper into the filter holder and assemble the apparatus as shown below. The sampling train should be set up so that the filter holder is outside the window. Be certain that the flowmeter is perfectly vertical.



2. Turn on the pump. Adjust the screw clamp so the flowmeter measures 15 liters per minute.
3. Allow the pump to run for 2 hours, then disconnect and remove the filter.
4. Place the filter in a Petri dish and cover it. Label the dish with the date, time, and weather conditions.
5. Repeat this procedure at the same time every day for two weeks.
6. Select one or two days which are smoggy, and repeat the experiment every two hours throughout the day starting from 8 a.m.

Results: At the end of the two weeks, examine the filters and compare differences in the shades of the stains. They could vary from white to black. The shade of the stain is an indicator of the amount of particulates present that day.

Note: If you intend to do Experiment E:1, save each filter in its Petri dish.

Discussion:

1. Can you see any relationships between the shades of the stains and the weather and visibility conditions?
2. On the days when you ran continuous experiments, examine the filters and determine if the shade of the stain changed at all during the day. Can you think of reasons why the stain could vary during the day?

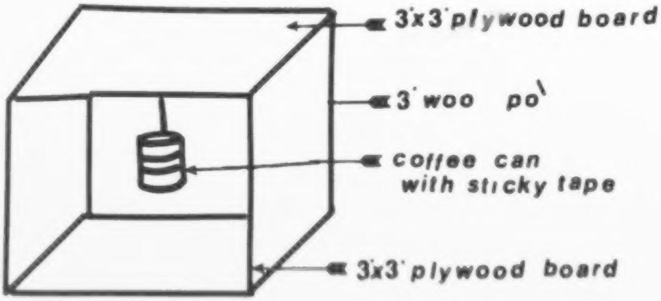
Experiment C:4 WHAT IS THE INFLUENCE OF WIND DIRECTION AND MAN'S ACTIVITIES ON PARTICULATES?

Objective: To determine the influence of wind direction and man's activities on particulates.

Materials: Sticky tape at least two inches wide, several empty one-pound coffee cans, shelters which are constructed as indicated:

Construction of a Shelter

The purpose of the shelter is to keep the rain off the tape, but still allow the tape to be exposed to the wind. There are many different ways such a shelter can be designed. One way is illustrated here.



Materials: 4—1" X 1" wooden poles, 3 ft. in length;
1—1" X 1" wooden pole, 1 ft. in length;
2—3' X 3' ½" exterior plywood boards.

Construction:

1. Use the 3-ft. poles as legs and nail them to the plywood boards as shown in the above diagram.
2. Place the 1-ft. pole into the coffee can and nail it to the bottom. Nail the other end of this pole to the center of one 3' X 3" plywood board.
3. To prevent the shelter from toppling over in high winds, it may be necessary to place several bricks on the plywood base.

Procedure:

1. Select a few sites in your community which will provide contrasts and comparisons in air quality. Consider residential, business, and industrial areas; traffic flow patterns; topography, and prevailing wind patterns. One taped can and shelter will be used at each outdoor site.
2. Assemble the shelters and place one can in each shelter according to the preceeding directions (see materials section).

3. Locate each shelter outdoors in an unprotected area where it is exposed to natural wind currents. One can also should be placed inside the classroom away from a window (a shelter is not necessary indoors).
4. Attach at least a two-inch width of sticky tape around the outside of each can to be used. Using a waterproof marker, label each tape with the location of the site. Also, indicate the points of the compass on the tape.
5. After 7 days, remove the tape from each can.

Results: Examine the tapes to determine which wind directions and locations result in the most and least particulates.

Discussion:

1. Compare the indoor and outdoor tapes.
2. Can you notice differences caused by the wind blowing from different locations?
3. Is there a difference by location?
4. What do you think are the sources of the particulates?

Experiment C:5 TESTING FOR MICROORGANISMS

Introduction: Microorganisms may be found in many types of environments including the atmosphere. They are one type of natural air pollutant.

Objective: To demonstrate that microorganisms are present in the air.

Materials: Ten sterile Petri dishes; 200 ml of sterile nutrient agar; magnifying glass; thermometer; an incubator or other place where the temperature can be maintained at 25° to 35°C (77° to 95° F) for 24 hours.

Procedure:

1. Prepare the sterile nutrient agar and cool it to approximately 45°C (113°F).
2. Aseptically pour 15 to 20 ml of agar into each Petri dish. Cover the dishes immediately and allow the agar to solidify.
3. Expose each dish at various locations both inside and outside the school for 20 minutes. Cover each dish immediately after exposure and indicate on its cover where it was exposed.
4. Incubate for 24 hours at 25° to 35°C (77° to 95°F). Record the temperature.

Results: Examine the Petri dishes. Record the characteristics and number of colonies found on each dish.

Discussion:

1. Does the number of colonies that develop in each Petri dish vary according to the exposure site?
2. Do the colonies differ in size, shape, and color? Why?
3. Discuss the importance of microorganisms to man and his environment.

Experiment C:6 ANALYSES OF POLLUTANT GASES

Introduction: As mentioned previously, there are three classes of pollutants: particulates, gases, and liquids. Particulates are easier to see because some fall out of the air, they reduce visibility, and they cause staining on filters. Gases, on the other hand, are more difficult to detect because you cannot see them. Consequently, sophisticated scientific techniques are needed to measure the amount of these pollutants in concentrations normally found in the atmosphere.

In high concentrations, pollutant gases can be measured by pollutant detector tubes. These tubes are available for many gases. This experiment illustrates the use of such tubes for the detection of carbon monoxide. The U.S. Air Quality Standard for carbon monoxide is 35 parts per million (ppm) for 1 hour and 9 parts per million (ppm) for 8 hours. Air containing concentrations below the standards is considered safe to breathe.

Objective: To demonstrate the presence of carbon monoxide gas in the air.

Materials: One carbon monoxide detector tube with a minimum detection level of 5 ppm; several refill cartridges.

(Normally, a cartridge can be used only once. However, if each subsequent test measures a higher concentration, the cartridge can be used more than once. For example, a single cartridge could be used to measure carbon monoxide concentrations in this order—10 ppm, 20 ppm, 30 ppm, etc. Once the cartridge measures 30 ppm, however, it cannot be used to measure concentrations of 30 ppm or lower again. Consequently, several refill cartridges may be required.)

Procedure:

1. In the school parking lot, use the detector tube to pull in a sample of air. Record the concentration of carbon monoxide. If the tube does not detect any carbon monoxide, the concentration is 5 ppm or less.
2. The teacher should turn on the ignition of a late-model automobile and collect a sample of air from near the car's tail pipe. Record the concentration. If possible, this experiment should be repeated using a pre-1968 automobile. (Beginning in 1968, the automobile industry began to install air pollution control devices in the exhaust systems of all new cars.)
3. At a busy intersection, use the detector tube to take a sample of air. Record the concentration.

Results: Compare the concentrations of carbon monoxide which were found.

Discussion:

1. What is the U.S. Air Quality Standard for carbon monoxide? Determine how this standard was chosen.
2. The automobile produces the major source of carbon monoxide by the incomplete combustion of gasoline. Discuss why the concentrations you measured were different. Why did the pre-1968 car produce more carbon monoxide?
3. Prepare a report on the history of air pollution control devices for automobiles.
4. When motor vehicles are properly tuned, less pollution is emitted. Make a survey of several people who drive to determine when their cars had their last tune-up.
5. Referring back to the text of Section C, list the major gaseous air pollutants and their origin.

Experiment C:7 ACID RAIN

Objective: To demonstrate whether acid precipitation occurs in your area.

Materials: Glass jar or plastic bucket to collect rain; distilled water; pH paper which indicates color changes for each 0.5 pH units and covers the range from 3.0 to 8.0 pH units.

Procedure:

1. Take a clean glass jar or plastic bucket and rinse it out three times with distilled water.
2. After rinsing, place the jar or bucket out in the rain or snow.
3. After collecting ½ inch of rain or 2 inches of snow, take the jar or bucket inside.
4. Immediately place a 3-inch strip of pH paper into the collected sample and observe the color change. (If the sample is frozen, allow it to melt before analyzing for pH.)
5. To determine the pH, compare the color of this pH paper to the chart supplied with the pH paper.
6. Repeat this procedure for a dozen or more storms throughout the year.

Results: Record the pH numbers and the dates on which they were sampled.

Discussion:

1. Does your community have acid rain?
2. Look at the map on Page [illegible], find the location of your community and determine the average precipitation pH of your area. Compare your measurements with this map. If they are different, can you think of any reasons for this?

D. SOURCES OF AIR POLLUTION

Pollutants in the air originate mainly from the incomplete combustion of fossil fuels for transportation, heating, and industrial production. However, in addition to combustion processes, air pollution is caused by vaporization (the change of a liquid to a gaseous state); attrition (the wearing away by friction, such as grinding, sawing, drilling, etc.); combustion of waste materials; chemical reactions in the atmosphere involving primary pollutants (the production of secondary pollutants); and to a lesser extent, natural sources such as pollination and volcanoes.

The major source categories of man-made pollutants are: transportation, stationary fuel combustion, industrial processes, and solid waste. These sources are classified as either mobile (moving sources) or stationary (fixed location sources) (See Table D-1).

Our present transportation systems rely on the combustion of fuels; consequently, air pollution is a by-product. These transportation sources include automobiles, trucks, buses, planes, farm equipment, trains, boats, etc. Because of their large number, automobiles are the dominant source in this category. Since 1963, when positive crankcase ventilation systems were installed, automobiles have been designed with air pollution control devices which have decreased the emissions from gas tanks, carburetors, crankcase vents, and tailpipes. For these controls to work effectively, it is necessary for the engine to be tuned and the carburetor to be adjusted properly. An improperly tuned engine will result in higher carbon monoxide and hydrocarbon emissions and lower fuel economy. The carburetor controls the air to fuel ratio. If the air to fuel ratio is too high, higher nitrogen oxide quantities result, while low air to fuel ratios will increase the amount of carbon monoxide and hydrocarbons as well as lower the fuel economy. Improperly cared for cars may have too rich a fuel mixture and therefore may waste fuel and produce more pollutants.

Incomplete combustion is a major cause of air pollution. Although complete combustion would result in the harmless products of carbon dioxide, water vapor, and ash, no combustion process is complete. Some pollutants are always released—whether they are the result of burning coal and oil in power plants, factories and homes, gasoline in motor vehicles, trash in incinerators and dumps, or leaf burning. However, at present, we would be without most of our electricity and transportation if the burning of fuels was eliminated.

Industrial processes also account for a large share of air pollution. Because of the tremendous diversity of the products of these industries, their

Table D-1

ESTIMATED EMISSIONS OF MAN-MADE AIR POLLUTANTS, NATIONWIDE 1977*

(10^6 metric tons/year)

Source category	Particulates	Sulfur oxides	Nitrogen oxides	Hydrocarbons	Carbon monoxide
Transportation	1.1	0.8	9.2	11.5	85.7
Stationary fuel combustion	4.8	22.4	13.0	1.5	1.2
Industrial processes	5.4	4.2	0.7	10.1	8.3
Solid waste	0.4	0	0.1	0.7	2.6
Miscellaneous	0.7	0	0.1	4.5	4.9
TOTAL	12.4	27.4	23.1	28.3	102.7

Note: A zero indicates emissions of less than 50,000 metric tons per year.

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*U.S. Environmental Protection Agency, "National Air Quality, Monitoring and Emissions Trend Report, 1977", EPA-450/2-78-052, Office of Air Quality Planning and Standards, Research Triangle Park, NC, December 1978.

production processes generate a wide range of pollutants. Major industries which contribute to air pollution include the petroleum and fuel industries, the chemical industry, and the metal industry.

Air pollution emissions generated during solid waste disposal are a relatively small, but still significant source. Air pollutants are produced by incineration and by the open burning of trash in dumps, etc.

Activities

1. Referring to Part C—Types of Air Pollutants, list the major pollutants and their sources.
2. Using Table D-1, compute the percentage of each pollutant for each major source category (transportation, stationary fuel combustion, industrial processes, solid waste, miscellaneous).
3. Draw pie charts or graphs for each air pollutant in Table D-1 illustrating the percent contributed by each major source.
4. Divide the class into groups. Each group should prepare a report on the air pollutants that are emitted by a different type of industry e.g. paint manufacturers, oil refineries, steel mills, paper mills, chemical industry.
5. Think of any one product that you use often. Make a list of the air pollutants that may be produced during its lifetime: raw material → production → use → disposal.
6. Take a walk around your town or city. If possible, go to a hill or tall building. List all the sources of air pollution that you can see. Then, on a map of your area, locate all the sources that you saw. Do they occur near a residential areas? If so, how might this affect the people who live there?
7. Research and report on sources of natural air pollution.
8. If possible, arrange one or more field trips to gather information on potential sources of air pollutants. Consider visiting:

   —the school heating system and the school incinerator (if one is present). Request an explanation of their operations and determine the type of fuel used by the heating system. What other types of heating systems could be used? Would they pollute more or less?

   —a local or regional solid waste dumping site. Determine if the refuse is disposed of by open burning, incineration, or landfill. Does your community use the same site for the disposal of its leaves?

   —a local or regional power generating plant. Request a tour through the operation and gather information on the fuel used, the air pollutants controlled, and the types of controls that are used.

   —a local automobile dealership. Request an explanation and, if possible, a demonstration of their automobiles' air pollution control devices.

   —an industrial plant. Request a tour through the operation. Gather information on the air pollutants controlled and the types of controls that are used.

9. Determine the amount of fuel used for heating your home last year. Then, determine the amount of each of the major pollutants released into the

air from heating using Table D-2 (e.g. 1 ton of coal would produce 10 pounds of carbon monoxide). If your home was heated by electricity, calculate the amount of each pollutant emitted from the burning of 500 gallons of fuel oil.

10. Determine the total amount of each of the major pollutants emitted last year from heating the homes of everyone in the class.

11. Find out what kind of fuel your school burns for heating and also what amount was used during each of the last twelve months. From Table D-2, calculate the amount of each of the major pollutants emitted into the air each month.

12. If a person owns a 1978 automobile and travels 20 miles a day, how many pounds of each of the pollutants listed in Table D-2 does the car contribute per year. Assume the fuel economy is 19 miles/gallon of gasoline.

13. One way in which a community can reduce air pollution from automobiles is to promote mass transportation. Determine where there are mass transit systems in your area. Are they sufficient to meet the community's needs?

14. If there is a mass transportation system, is it being used by many people? If not, suggest ways to increase the ridership.

15. Survey some residents in your area who have lived there for many years. Do they believe there are fewer or more air pollution sources? Has the air pollution decreased or increased?

References

(1) THE AIR CONSERVATION COMMISSION. Pollutants and their effects (pg. 60-158) in Air Conservation and Public Policy, American Association for the Advancement of Science, The Horn-Shafer Co., Baltimore, MD, 1965.

(2) FAITH, W. and A. A. ATKISSON, JR. Stationary Sources (pg. 216-243), Transportation Sources (pg. 257-294) in Air Pollution, Wiley Interscience, NY, 1972.

(3) LEDBETTER, J. O. Air Pollution, Part A - Analysis, Marcel Dekker, Inc., NY, 424 pp., 1972.

(4) STOKER, H. S. and S. S. SEAGER. Environmental Chemistry, Scott, Foresman and Co., Glenview, IL, 186 pp., 1972.

Table D-2

EMISSION RATES OF COMMON POLLUTANTS FROM SEVERAL TYPES OF SOURCES

Source	Fuel	Emission rate units	Emission Rate Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur dioxide	Particulates
Home heating	Coal (bituminous)	Pounds/ ton	10.0	3.0	6.0	38 X % S*	16.0
Home heating	Fuel oil	Pounds/ 1000 gal.	5.0	1.0	18.0	142 X % S*	2.5
Home heating	Natural gas	Pounds/ million cubic ft.	20.0	8.0	80.0	0.6	10.0
Automobile (1978)	Unleaded gas	Pounds/ 1000 gal.	628	62.8	83.7	8.4	15.9

*Note: Coal and fuel oil emission rates for sulfur dioxide depend on the amount of sulfur in the fuel. To obtain their sulfur dioxide emission rates, multiply the number in the table by the % sulfur (S) in the fuel.

Sources: Environmental Activities Staff, "Pocket Reference", General Motors Tech. Center, Warren, MI, April 1979; M. Sittig, Environmental Sources and Emissions Handbook, Noyes Data Corp., Park Ridge, NJ, 1975; U.S. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors", AP-42, U.S. EPA, Washington, DC, August 1977.

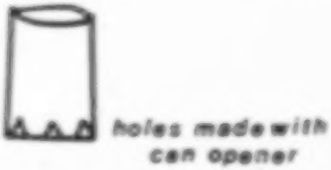
Experiment D-1 A DEMONSTRATION OF INCOMPLETE COMBUSTION

Objective: To determine that incomplete combustion occurs as a result of the burning of fuel with inadequate oxygen.

Materials: Newspaper; safety matches; 2 empty, clean metal cans of equal size (approximately 16 oz. size); can opener.

Procedure:

1. Use the can opener to make 6 holes in the bottom of one of the cans as shown.



2. Roll 2 pieces of newspaper into 2 cones and stuff their small ends into the two cans. The tops of the cones should extend about 4 inches out of the cans. In this experiment, the newspaper is the fuel that is burned.
3. Using safety matches, light the top of each cone.

Results: Observe: the rate at which both papers burn, the amount of smoke produced from each, and the amount of residue left when the burning ceases. Record the information.

Discussion:

1. In which can did the most efficient combustion occur? How can you tell? Why was combustion more efficient?
2. With incomplete combustion, fuel is wasted and pollution is produced. The more incomplete the combustion process, the more pollution is generated. What happens when incinerators, furnaces, and engines have incomplete combustion?

EXPERIMENT D-2 THE IMPACT OF THE AUTOMOBILE ON AIR QUALITY

The automobile is a major source of air pollution in many urban areas. Pollution from automobiles results from the incomplete combustion and evaporation of gasoline which is composed of various blends of hydrocarbons. Starting in 1963, the automobile industry began to install pollution-control devices to reduce evaporative emissions, and in 1968, the industry began to install controls to reduce exhaust emissions.

Automobiles in the United States burn approximately 80 billion gallons of gasoline per year. This usage increases by 4% annually and is responsible for 75% of the carbon monoxide (220,000 tons per day), 35% of the hydrocarbons (28,000 tons per day), and 29% of the nitrogen oxides (19,000 tons per day).

Carbon monoxide is toxic in high concentrations. Hydrocarbons combine with other pollutants such as nitrogen oxides in the presence of sunlight to produce ozone and other secondary pollutants associated with photochemical smog. Photochemical smog may produce eye irritation, plant damage, respiratory irritation, and decreased visibility.

A car pollutes the air (1) from the gas tank (hydrocarbons); (2) from the carburetor (hydrocarbons); (3) from the crankcase vent (hydrocarbons), and (4) from the tailpipe (hydrocarbons, carbon monoxide, nitrogen oxides, and a small amount of particulates).

Objective: To demonstrate that automobiles and other motor vehicles are a source of air pollution.

Materials: Three ft. X 4 in. posterboard; scissors; ruler; white facial tissues; masking tape. If possible, a variety of automobiles (pre-1968, early 1970's, late 1970's, 1980's, and diesel models), trucks and motorcycles should be available for sampling.

Procedure:

1. Prepare a collector board by cutting a 2" X 2" hole three inches from one end of the posterboard or cardboard. Over the hole, place a 3" X 3" piece of white facial tissue and tape the edges with masking tape.
2. Prepare a chart listing: the type of vehicle, model year, manufacturer, type of fuel burned, and the approximate length of time since the last tune-up.
3. Caution. Do not touch a tailpipe during these procedures, because it will be hot when the engine is running. Also, keep your face as far away as possible from the exhaust, because invisible, toxic pollutants are emitted by running engines. Before you start, be certain to obtain permission from the operator of the motor vehicle to perform this test.
4. Sample the tailpipe emissions from as many different vehicles as possible. The engine should be warmed up

for 5 minutes before the sample is taken. For one minute, the teacher should hold the collector board 4 inches away from the mouth of the exhaust tailpipe of a vehicle while the engine is idling. (Hold the collector board so that the tissue is facing the tailpipe.)

5. Record the vehicle's information on the chart which was prepared. Also, tape to the chart the facial tissue that was exposed to the exhaust.
6. For a different vehicle, mount a new 3" square piece of white facial tissue to the board. Take a 1-minute sample while this vehicle is idling. Record the information and save the tissue paper.
7. Repeat these procedures several times with different vehicles.

Results: Compare the color of the particles on the facial tissue samples from the various vehicles. Next, place the samples on a bulletin board, record the vehicle information that was collected (type and model year, etc.) on cards, and arrange each card under the appropriate sample. Compare the information.

Discussion:

1. Discuss the results of this experiment.
2. Obtain information on the types of air pollution control devices which automobile manufacturers have installed. Draw an automobile and label the points where pollutants are emitted. What has been done to reduce these sources? How much have they been reduced?
3. Find out the type, model, and year of your parents', friends', and teachers' automobiles. Ask them how many miles they travel in a year. Using Table D-3, calculate the pounds of pollutants (hydrocarbons, carbon monoxide, and nitrogen oxides) they produce each year. Notice how much less pollution the newer cars with pollution control devices produce.
4. Older cars (early 1970's and older) are a major source of lead, an extremely toxic substance. Why are new cars no longer important sources of lead?
5. What are some federal and state regulations regarding automobile pollution control devices?
6. A properly tuned automobile emits substantially less pollution that one that is not. How often does your family automobile have its engine tuned and carburetor adjusted?
7. What are some alternatives to using automobiles for transportation? Why are they valuable?

Table D-3

MAXIMUM ALLOWABLE EMISSIONS FOR LIGHT DUTY GASOLINE-POWERED VEHICLES IN THE UNITED STATES (EXCLUDING CALIFORNIA)

	Grams per mile		
odel year	Hydrocarbons	Carbon monoxide	Nitrogen oxides
960-1967	10.6	84	4.1
968	6.3	51	4.4
969	6.3	51	5.0
970	4.1	34	4.4
971	4.1	34	4.3
972	3.0	28	4.6
973	3.0	28	3.1
974	3.0	28	3.1
975	1.5	15	3.1
976	1.5	15	3.1
977	1.5	15	2.0
978	1.5	15	2.0
979	1.5	15	2.0
980	0.41	7	2.0
981-1983	0.41	3.4	1.0

Pounds of pollutants/year = grams/mile X miles/year X 1 lb/454 grams.

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ource: U.S. Environmental Protection Agency, "Mobile Source Emission Factors", EPA-400/9-78-005, Office of Air and Water Management, Washington, DC, 1978.

E. EFFECTS OF AIR POLLUTION

1. Human Health

Air pollution can affect man and his environment in several ways. When the concentration of air pollutants increases without being adequately dispersed because of meteorological, topographical, or other factors, serious health problems may result. Several acute episodes have occurred in the past, e.g. Meuse River Valley, Belgium, 1930; Donora, Pennsylvania, 1948; London, England, 1952; and New York City, New York, 1966. In each case, an inversion trapped the pollutants causing more illness and death than usual—especially among the elderly and among people with pre-existing heart and lung conditions.

Although estimates of mortality due to air pollution range from 0.1% to 10%, even the 0.1% effect of air pollution would account for 15,000 annual deaths from air pollution. This figure is the estimate made by the National Academy of Sciences/National Academy of Engineering. Persons living in urban areas have a greater risk of being exposed to air pollutants which can affect their well-being.

The respiratory tract is affected by air pollution. The cilia in the nose and inner surfaces leading to the lungs may trap the larger particles of pollutants; however, smaller particles and gases are able to enter the lung. When we breathe, balloon-like sacs in our lungs, called alveoli, exchange oxygen for carbon dioxide. Pollution may cause some of these alveoli to enlarge and lose their resiliency, so that it is more difficult to breathe. Air pollutants also can slow down or stop the action of cilia which would normally carry mucus and trapped pollutants out of the respiratory tract. The mucus may thicken or increase and the airways may become constricted. Breathing problems can result because of one or more of these reactions. Also, microorganisms and other foreign matter may not be sufficiently removed making the respiratory tract susceptible to infection.

Air pollution has been associated with chronic respiratory disease. Air pollutants can cause bronchial asthma attacks. During such attacks, there is a temporary widespread narrowing of the smaller airways (bronchioles) produced by a muscle spasm, an increase in mucus secretions, or a swelling of the mucous membrane. Air pollutants aggravate both chronic bronchitis and pulmonary emphysema. In chronic bronchitis, an abnormal amount of mucus is produced in the bronchi, a recurrent cough results, and other diseases that would cause such a cough are absent.

Pulmonary emphysema is characterized by a breakdown of the walls of the alveoli. In the course of this disease, irreversible tissue damage occurs. The alveoli become enlarged, lose their resilience, and disintegrate. Shortness of breath is a symptom of this disease. In lung cancer, there is an abnormal growth of cells originating in the bronchial mucous membrane. Although it is unlikely that lung cancer is produced by any one cause, air pollutants may paralyze the cilia and permit carcinogenic substances to remain in contact with the bronchial cells longer than normal. In addition, some air pollutants have been identified as substances capable of causing cancer, e.g. certain hydrocarbons (benzopyrene).

There is a close association between the respiratory and circulatory systems. If the respiratory system is affected by disease and cannot exchange the gases in the blood completely, the heart must work harder to pump enough blood to make up for the loss of oxygen. As a result, the heart and blood vessels are under stress and may undergo change—such as an increase in size of the heart. Because carbon monoxide can reduce the oxygen content of the blood, this pollutant can add an additional burden to persons with anemia or a cardiorespiratory disease.

Air pollutants may have other effects which include: burning, tearing eyes; blurred vision; dizziness; headache; throat irritation; sneezing and coughing; impaired performance.

In addition to the man-made pollutants, natural pollutants are ubiquitous. The major natural pollutants which adversely affect health are aeroallergens. Aeroallergens consist chiefly of pollens but also include bacteria, molds, spores, house dust, and vegetable fibers, etc. Well over 10% of the exposed population in the United States is affected by aeroallergens. The major health effects are: allergic rhinitis and/or bronchial asthma with reversible tissue change. Infectious complications may result and may aggravate the health effects of man-made air pollutants.

Pollens from plants, ragweed in particular, produce the most important allergens. Pollen counts are taken daily in many areas during the pollen season. These counts serve as an indicator of the amounts of allergens in the air.

Animals may also be affected by air pollutants. In the past, when acute episodes of air pollution produced illness in humans, many animals also became seriously ill and some died. However, the effects appear to vary according to the species of animal.

Activities

1. Draw a diagram of the respiratory system, discuss its structure and function, and show how air pollution may affect it.
2. There have been several air pollution episodes in recent history, e.g. Meuse Valley, Belgium, 1930; Donora, Pennsylvania, 1948; Poza Rica, Mexico, 1950; London, England, 1952; Eastern United States, 1962 and 1966, etc. Report on one of these and describe the health effects that occurred.
3. Discuss why plants produce pollen. Sketch a ragweed plant and leaf or bring into class a ragweed leaf from your neighborhood. Why is ragweed important? What other types of plants produce pollen which may cause allergic reactions?
4. Determine whether pollen counts are taken in your area. If so, where are they taken?

References

(1) Air Pollution and Your Health. Leaflet available from EPA, Region II, 26 Federal Plaza, NY 10007.

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2. Vegetation

Many plants are sensitive to air pollutants. Some are used as indicators of air pollutants because they demonstrate a characteristic type of damage to a specific pollutant.

Air pollutants enter a leaf principally through the pores or stomata. Although some pollutants can be rendered harmless by the plant, others will cause damage. The extent of damage varies because of several factors: the characteristics of the pollutant (concentration, duration, chemical and physical properties, etc.); climatic conditions (temperature, light intensity, precipitation, etc.); soil conditions (moisture, nutrients, etc.), and biological factors (stage of development, genetic composition, insects, disease, etc.).

Air pollutants affect many types of vegetation, including agricultural crops. Air pollution affects agriculture by: decreasing the value of the product (the quantity or the quality may be affected, and time of marketing may be delayed or hastened), or increasing the cost of production (decreasing the value of the crop, requiring additional fertilizer, irrigation, etc.).

Different species of vegetation and varieties within a species differ in their susceptibility to particular pollutants. The major pollutants which cause plant damage and some of the species which are affected are listed in Table E-1.

Activities

1. In the early 1900's, both Anaconda, Montana, and the Ducktown-Copperhill area of southeastern Tennessee had dramatic air pollution damage to vegetation. Report on the extent of the damage and its cause for one of these areas.
2. Write to your county agricultural agent requesting information on vegetation damage in your county and state due to air pollution. If time allows, invite the county agent to speak on this topic.
3. Compare the vegetation that is growing near a heavily travelled road with similar vegetation that is growing farther away from the road. Examine the leaves with a hand lens. Compare leaves from both locations for:

   A. differences in the amount of dust on the leaves;
   B. differences in the appearance of leaves from the same type of plant.

References

(1) JACOBSON, J. S. and A. C. HILL (Eds.). Recognition of Air Pollution Injury to Vegetation = A Pictorial Atlas, Air Pollution Control Association, Pittsburgh, PA, 1970.

(2) MANSFIELD, T. A. Effects of Air Pollutants on Plants, Cambridge University Press, London, England, 209 pp., 1976.

(3) Medical and Biologic Effects of Environmental Pollutants, Ozone and Other Photochemical Oxidants, Plants and Microorganisms (Chapter 11), National Academy of Science, Washington, DC, 1977.

(4) MUDD, J. B. and T. T. KOZLOWSKI. Reponses of Plants to Air Pollution, Academic Press, New York, NY, 383 pp., 1975.

(5) TRESHOW, M. Environment and Plant Response, McGraw-Hill, Co., New York, NY, 422 pp., 1970.

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Table V-[illegible]

SUMMARY OF POLLUTANTS, SOURCES, SYMPTOMS, AND VEGETATION AFFECTED*

Pollutants	Sources	Symptoms	Age of Leaf Affected	Part of Leaf Affected	Examples of Susceptible Species
Ozone (O_3)	[illegible]	[illegible]	Old, progressively to young	Palisade	Tomato, tobacco, bean
Peroxyacetyl nitrate (PAN)	Same sources as ozone.	Glazing, silvering, or bronzing on lower surface leaves.	Young	Spongy cells	Petunia, romaine, lettuce
Nitrogen dioxide (NO_2)	High-temperature combustion of coal, oil, gas, and gasoline in power plants and internal combustion engines.	Irregular, white or brown collapsed lesion on intercostal tissue and near leaf margin.	Middle-aged	Mesophyll cells	Pinto beans, tomatoes
Sulfur dioxide (SO_2)	Coal, fuel oil, and petroleum.	Bleached spots, bleached areas between veins, bleached margin, chlorosis, growth suppression, early abscission, and reduction in yield.	Middle-aged	Mesophyll cells	Alfalfa, cotton, tulip, barley
Hydrogen fluoride (HF)	Phosphate rock processing, aluminum industry, iron smelting, brick and ceramic works, and fiberglass manufacturing.	Tip and margin burn, chlorosis, dwarfing, leaf abscission, and lower yield.	Mature	Epidermis and mesophyll	Gladiolus, peach, corn
Chlorine (Cl_2)	Leaks in chlorine storage tanks; hydrochloric acid mist.	Bleaching between veins, tip and margin burn, and leaf abscission.	Mature	Epidermis and mesophyll	Alfalfa, radish
Ethylene (CH_2)	Incomplete combustion of coal, gas, and oil for heating, and automobile and truck exhaust.	Sepal withering, leaf abnormalities; flower dropping, and failure of flower to open properly.	(Flower)	All	Orchid

*Adapted from: I. J. Hindawi, "Air Pollution Injury to Vegetation", U.S. Department of Health, Education, and Welfare, Raleigh, NC, 1970.

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3. Materials

Air pollutants can: corrode and tarnish metals; crack rubber; soil clothing, furnishings, buildings, etc.; erode buildings, monuments, etc.; discolor many types of materials; weaken cotton, wool, and silk fibers; and destroy nylon.

Reactive gases, such as ozone and sulfur dioxide, as well as acids, such as sulfuric and nitric, are mainly responsible for damaging textiles, discoloring dyes, tarnishing metals, weakening rubber, and eroding buildings. Particulate matter is mainly responsible for soiling our environment.

Activities

1. Observe the buildings and statues in your area. Note if any of them are being eroded or soiled.
2. Place a handkerchief on a clean desk or table and allow the top of the desk or table to be undisturbed for 3 days. After that time, carefully remove the handkerchief. Compare the amount of dust that has settled on the exposed area to the amount on the area that was covered.
3. List the cleaning jobs around your home and school which are made necessary by air pollution.
4. Look at the outside of your windows. Note the thin film of particles that have formed. Determine how often the windows have to be cleaned and how much time and money is spent on window cleaning. This is a direct cost of air pollution.

References

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(2) LEDBETTER, J. O. Effects of Air Pollution (pp. 363-406) in Air Pollution, 424 pp., 1972.

(3) YOCUM, J. E. and UPHAM, J. B. "Effects on Economic Materials and Structures", In: A. C. Stern (ed.), Air Pollution, Vol. II, 3rd ed., pp. 65, 1976.

4. Weather

Air pollution may reduce visibility and create a hazard for transportation. Impaired visibility is easily noticed and is especially objectionable when it causes scenic vistas such as the Grand Canyon, the Rocky Mountains, etc. to become less visible. Impaired visibility results in a decrease in the visual range (the distance over which people can see objects). If air pollutants or natural dust are not present, the visual range at sea level is limited only by topography or the scattering of light by naturally occurring gases and fog.

Air pollution may also cause a discoloration of the atmosphere. This has been observed in many cities throughout the United States, but probably the most famous is the Denver "brown cloud." This cloud is particularly noticeable because it blocks out the views of the Rocky Mountains which are only 20 miles to the west of Denver. Most of the impaired visibility and brown discoloration in Denver and in the rest of the U.S. is caused by the scattering of light by particulates too small to be seen without the aid of a microscope. These particulates have diameters between 0.3 micrometers ($\frac{1}{760,000}$ of an inch) to 1.0 micrometer ($\frac{1}{254,000}$ of an inch). In some places, the brown discoloration is enhanced by nitrogen dioxide which is a brown-colored gas.

As you learned in Lesson 4, stationary and mobile sources emit particulates, many of which are very small, and hence, capable of scattering light. Also, under certain conditions, the sulfur dioxide, hydrocarbons, and nitrogen oxides gases emitted from these sources may undergo chemical reactions in the presence of sunlight to produce many more particulates. This may result in large areas hundreds of miles wide being engulfed by a hazy "blob" of air. To complicate matters, the removal processes for these particulates are extremely slow in the absence of precipitation. They may travel hundreds of miles from their source and affect other areas—including rural areas with few man-made sources of pollutants.

The reduction in visibility by pollutants is certainly the most visible effect on our atmosphere. There are, however, several other known or postulated effects—some of which could be potentially more serious. These are summarized below.

1. Enhancement of fog formation. Normally, fog occurs when the relative humidity reaches 100%. However, certain particulates such as sulfates and nitrates attract water and can cause fog at relative humidities slightly below 100%.
2. Increasing precipitation. Many of the small particulates serve as excellent nuclei for cloud droplet formation. Consequently, this may cause increased precipitation downwind of large sources of particulates.
3. Global temperature changes. There are two opposing factors to be considered. First, carbon dioxide (CO_2) concentrations have been steadily increasing for the past several decades. Carbon dioxide is emitted from all combustion processes; however, it is not generally

considered to be an air pollutant. Since CO_2 traps the sun's heat in the lower atmosphere, increased CO_2 could result in increased global temperatures. Some scientists feel this could lead to a partial melting of the polar ice caps which would cause the oceans to rise and flood certain coastal cities.

The second factor to be considered is the effect of small particulates which intercept some of the sun's energy and prevent it from reaching the ground. This could result in a decrease in surface temperature.

Conclusive evidence which supports either of these phenomena has not been observed. However, as emissions increase, there is a greater likelihood that some effect will become noticeable.

4. Depletion of ozone in the atmosphere. Twenty-five kilometers above the earth's surface in the stratosphere, a layer of natural ozone exists. This ozone layer is extremely important to life, because it absorbs much of the sun's ultraviolet radiation. Most of the life on earth would perish if this layer were eliminated. Exhaust gases from aircraft flying in the stratosphere (e.g. the SST) and fluorocarbons deplete the ozone. Fluorocarbons have many uses, but the most common are refrigeration and air conditioning systems, industrial uses, and aerosol can propellants. These chemicals are extremely inert and are not destroyed to any great extent by natural processes except ultraviolet radiation. Consequently, when the fluorocarbons are released in the atmosphere, they accumulate. The fluorocarbons eventually migrate to the ozone layer and encounter ultraviolet radiation which destroys them and forms other products which destroy the ozone. It is not known how much ozone will be destroyed by this process, but some scientists think that it will result in an increase in skin cancer. Consequently, fluorocarbons have been banned from many uses.

Activities

1. Discuss how various forms of transportation may be affected by impaired visibility.
2. Look out your school windows on a clear day and observe the farthest building that can be seen. Determine the distance between you and this building by using a map or other means. Repeat this every day and maintain a record of: your observations, the Pollution Standards Index (if available), and meteorological conditions. Discuss any relationship between them.

3. Determine what has been done legislatively to protect scenic areas from visibility deterioration. Are there any areas in your state which are being protected?

4. Carbon dioxide emissions are increasing faster than natural processes can remove them from the atmosphere. Find out what the most important natural removal process is.

5. Determine what laws have been passed to protect the ozone layer.

References

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(2) LEDBETTER, J. O. Air Pollution, 1972.

(3) NATIONAL ACADEMY OF SCIENCES. "Protection Against Depletion of Stratosphere Ozone by Chlorofluorocarbons", Washington, DC, 1979.

(4) ROBINSON, E. and R. J. VALENTE. 1982, Atmospheric Turbidity Over the U.S. from 1967 to 1976, U.S. EPA-6000/S3-82-07G, Environmental Sciences Research Laboratory, Research Triangle Park, NC 27711.

(5) WILLIAMSON, S. J. Fundamentals of Air Pollution, Addison-Wesley Publication Company, Reading, MA, 1973.

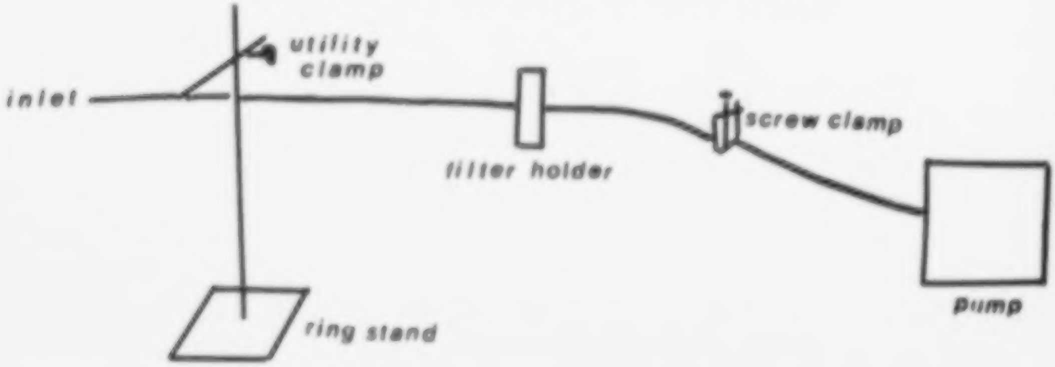
Experiment E:1 CIGARETTES PRODUCE AIR POLLUTION

Objective: To demonstrate that cigarette smoke produces air pollutants including particulates.

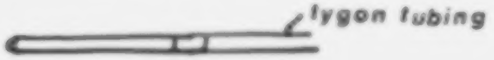
Materials: Cigarettes; matches; 47 mm diameter white glass fiber or paper filter paper; 47 mm filter holder; vacuum pump capable of pulling 20 liters per minute; thick-walled Tygon tubing; screw clamp; ring stand assembly; and a utility or buret clamp.

Procedure:

1. Place a piece of filter paper into the filter holder and assemble the apparatus as shown below.



2. Turn on the pump and reduce the air flow by closing the screw clamp so that there is only a slight suction felt when a hand is placed over the inlet of the Tygon tubing.
3. With the pump running, place the filter tip end of the cigarette into the Tygon tubing that is supported by the utility clamp. Push the cigarette into the tubing just far enough so that it does not fall out. If the Tygon tubing is too large to securely hold the cigarette, use a twist-tie to make the fitting snug.



4. Light the cigarette.
5. Allow the cigarette to burn down as far as possible without burning the Tygon tubing. Then, turn off the pump and extinguish the cigarette by pouring water on it.

Results: Remove the filter from the holder and observe the stain.

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Discussion:

1. Compare the stain obtained from this experiment with those obtained from Experiment C:3. Are there more stain-producing particulates in the air or in cigarette smoke? Remember, the air was sampled for 2 hours, while the cigarette smoke was sampled for less than 5 minutes.

2. Cigarette smoke may be inhaled into the lungs. Report on what effects the residue, which accumulated on the filter paper, could have on your lungs.

3. Both meteorology and topography influence the concentrations of other air pollutants that were previously discussed. What conditions would permit cigarette smoke concentrations to increase?

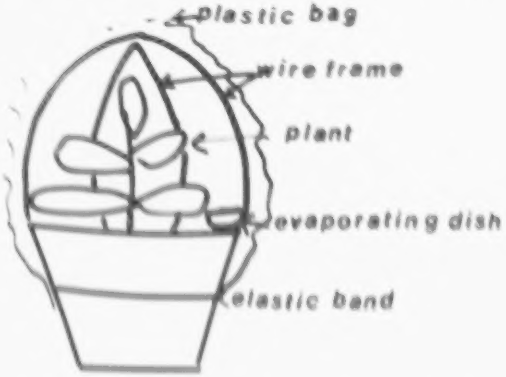
Experiment E:2 THE EFFECTS OF SULFUR DIOXIDE ON PLANTS

Objective: To observe the effects of sulfur dioxide on plants.

Materials: Two wax begonias or two zinnias which are potted in two 6-inch clay or plastic pots; coat hangers or suitable wire to construct 2 frames; plastic bags to fit over the wire frames; elastic bands; small evaporating dish; sodium sulfite (Na_2SO_4), and dilute (0.1 Normal) hydrochloric acid (HCl).

Procedure:

1. To support the plastic bag over one plant, construct a frame out of the wire or coat hangers as shown below.



2. Place ½ of a teaspoon of sodium sulfite into the evaporating dish. Add 1 teaspoon of 0.1 N hydrochloric acid. This reaction will produce sulfur dioxide. Set the evaporating dish on the soil next to the plant.
3. Immediately put the plastic bag over the wire frame and pot, and make it air-tight with the elastic band.
4. Place the plant in sunlight.
5. The second plant is the control. Place the second plant in a frame and plastic bag near the first so that it receives similar light.

Results: After two days, remove the bags from the plants. Examine the plants and compare the differences between the two plants.

Discussion: Is there any damage on the plant exposed to sulfur dioxide? If so, on what part of the plant did the damage occur? How might this affect the plant?

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Experiment E:3 VEGETATION AS INDICATORS OF AIR POLLUTANTS: AN AIR POLLUTION GARDEN

Objective:

1. To detect the presence of gaseous pollutants in the air through their specific effects on certain sensitive indicator plants.
2. To observe the effects of air pollution on plants.

Materials: Seeds for indicator plants (see Step 1 in Procedure); flower pots; potting soil; a small outdoor area for growing the plants (if no area is available, plants can be grown in 1-gallon flower pots); access to water; fertilizer.

Procedure:

1. Select one or more of the indicator plants for each pollutant listed in Table E-2 and obtain seeds for them. By planting more than one type of indicator plant for each pollutant, symptoms can be checked on more than one species. This will increase the reliability of the diagnosis. Also, more than one plant per species should be planted.
2. Find out from your local county agricultural extension service the expected date of the last killing frost in your area. Start the seeds in the pots six to eight weeks before the last expected frost. Keep them on a sunny window sill and water them several times a week, as needed.
3. Several days after the last expected killing frost, set the plants outside in a sunny location. Continue to water them several times a week unless rainfall is abundant. Apply fertilizer if necessary to maintain vigorous growth. Listen to daily weather forecasts, and if a frost is predicted, take the plants that are in pots inside for the night.
4. Observe the garden regularly and record the presence of foliar injury. Devise a system to distinguish leaves injured on a certain date so that subsequent occurrences of injury can be distinguished. (e.g. A small strip of red cloth or a string could be tied around the base of a leaf to indicate the presence of injury on a certain date while another color cloth could be used for a later date.) Keep a record of the system that is used to distinguish the dates of foliar injury.
5. Keep a daily record of the weather conditions: record the amount of sun or cloudiness, wind direction and speed, precipitation, and minimum and maximum daily temperature. If the Pollutant Standards Index (PSI) is available in your area, also record this data.

Table E-2

Pollutant	Indicator plant	Symptoms
Sulfur dioxide	Wax begonia; squash	Yellow, tan, or ivory papery blotches on leaf between veins. Veins usually stay green. Injury normally extends through the leaf.
Ozone	Pinto or green beans	Dark stipple (dots or very small spots) on upper leaf surface.
	Spinach	White bleached area on upper leaf surface.
	Pumpkin; melon	Light fleck on upper leaf surface.
Peroxyacetyl nitrate	Swiss chard; lettuce	Glazed or bronzed appearance on under surface of leaf.
Hydrogen fluoride	Gladiolus; corn	Tips and margins of leaves turn pale green to yellow or tan and finally to a dark reddish brown.

Results: Compare the information on plant damage, Pollutant Standards Index, and meteorological conditions.

Discussion:

1. Discuss which plants were affected by air pollution damage and the types of injury that were observed.
2. Were there any days when significant amounts of damage occurred? If so, what are some possible causes.

EXPERIMENT E:4 THE EFFECTS OF HOUSEHOLD AIR POLLUTANTS ON PLANTS

Objective: To study the effects of household air pollutants on plants.

Materials: Bean seeds; soil; 5 six-inch clay or plastic flower pots; coat hangers or suitable wire to construct frames; 5 plastic bags to fit over the wire frames; 5 elastic bands; twist-ties; 4 aerosol cans of common household products such as furniture polish, window cleaner, deodorant, hair spray, etc.

Procedure:

1. Plant the seeds in 5 separate six-inch clay or plastic pots. (Plant 4 seeds per pot.) Arrange the pots in the same general area, giving them the same care. When the plants are approximately 1½ inches tall, throw away the weakest plants in each pot leaving one plant in each pot.
2. Make five mini-greenhouses to cover the five plants. The procedure for constructing the mini-greenhouses is given in Experiment E:2.
3. Label each of the four pots with the name of a different aerosol which will be used. (Pot #5 is the control.)
4. Place all five plants in the same area so they will have a similar light exposure.
5. Poke a hole in the top of each bag to allow the aerosol to be sprayed into the bag.
6. Each day for two weeks, spray for five seconds through the holes with the appropriate aerosol (e.g. deodorant aerosol in the deodorant-labeled pot). After spraying, close the hole with a twist-tie to prevent the aerosol from escaping the bag. The fifth plant will not be sprayed, because it is the control.
7. Water the plants when the soil becomes dry.

Results: Observe the plants daily, and keep a record of these daily observations.

Discussion:

1. What can be concluded from this study?
2. What safety precautions should be taken when you use various types of aerosol products?
3. Do you think any of these aerosols might have a harmful effect on man or his environment?

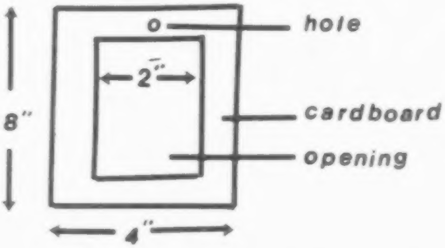
Experiment E:5 THE EFFECT OF AIR POLLUTANTS ON MATERIALS

Objective: To demonstrate that air pollutants in the atmosphere can have a detrimental effect on certain materials.

Materials: Six ½ inch threaded hooks; 6 ft. of rigid wire; 4 cardboard frames (described below); 1 ozone sensitive rubber band (available from B. F. Goodrich Research Center, Brecksville, Ohio 44141, Attention: Mr. R. Beatty); 1 high relative humidity ozone gas fading control fabric (fabric #129, available from the American Association of Textile Chemists, Research Triangle Park, North Carolina); 1 low relative humidity ozone gas fading control fabric (fabric #109) and 1 combustion sensitive fabric ribbon (ribbon #1, both available from Test Fabrics, 200 Blackford Avenue, P. O. Drawer O, Middlesex, New Jersey 08846; 1 good quality (15 denier) nylon hose; contact cement or non-water base glue; 1 varnished block of wood 1"X8"X4"; 1 shelter (described in Experiment C:4); aluminum foil; 2 thumb tacks.

Procedure:

1. Construct 4 cardboard frames (figure shown below) from cardboard or heavy posterboard.



2. Screw 5 hooks inside the top section of the shelter in a circle 12 inches from the center, and space them equally apart.
3. Cut sections of each of the two fabrics, the ribbon, and the hose of sufficient size to cover the opening in the frame. Glue each section to a frame so it covers the opening.
4. On each frame, poke a hole for the wire in the center of one (4-inch) side. Use the wire to hang the frames from the hooks in the shelter. They should hang approximately 15 inches from the top of the shelter.
5. Take the wooden block (figure shown below) and screw the remaining hook into the center of the top. Cut a 4-inch length of the ozone sensitive rubber band. Stretch the 4-inch rubber band to 5 inches and fasten it to the block of wood with thumb tacks. Fasten a length of wire to the hook on the block and hang it approximately 15 inches from the top of the shelter.

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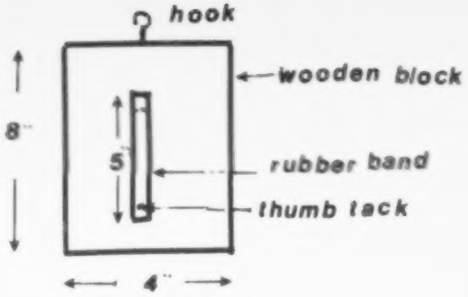


6. Allow the test materials to be exposed to the ambient air for 1 month. In some very clean areas, a one-month exposure may not be sufficient to produce any damage. If no damage is observed after one month, expose the same materials for another month. In certain areas, ozone damage may not be observed until the warmer months.

7. Repeat this experiment several times during different months using new fabrics, ribbons, hose, and rubber bands.

Results:

1. Observe the test materials daily and note if any changes have occurred. Also, record daily meteorological conditions and the Pollutant Standards Index.

2. At the end of each month, examine the test materials, completely wrap them in aluminum foil, and store them for future observations.

3. Before the close of the school year, compare all the monthly samples.

Discussion:

1. Which test materials showed damage?

2. Compare the dates on which damage occurred with your daily records on meteorological conditions and the Pollutant Standards Index.

3. Compare the month to month variations in the damage to the test materials. Discuss some possible causes for them.

4. List several items that are made out of the materials used for this experiment. How would air pollution affect them?

EXPERIMENT E-6 THE EFFECT OF AIR POLLUTION ON VISIBILITY

Introduction: Particulates in the air absorb or scatter light and can cause a marked reduction in visibility. Relative humidity and precipitation by themselves, or in conjunction with air pollution, also contribute to reduced visibility.

Objective: To estimate visibility and relate it to relative humidity, precipitation, and pollution observations.

Materials: Map; wet and dry bulb thermometer; table relating wet and dry bulb temperatures to relative humidity.

Procedure:

1. Select a location with a view of several miles (hill or second story window.
2. Using the map, select landmarks approximately ½, 1, 5, 10, 20, and 30 miles away.
3. Each day for several weeks between 12 noon to 2 p.m., note the farthest landmark visible and determine the distance to it.
4. Find out what the relative humidity is from the radio or your local weather service office. If this information is not available from these sources, obtain a wet and dry bulb thermometer and follow the manufacturer's directions to obtain the relative humidity.
5. Note whether precipitation is occurring.
6. If available, determine the Pollution Standards Index value for particulates.

Results: Record for each date of observation: the distance to the farthest visible landmark, the relative humidity, precipitation (if present), and the Pollution Standards Index.

Discussion:

1. If you cannot see the farthest landmark, what could have caused the visibility reduction?
2. What type of human activities could contribute to the reduction in your visibility?
3. Can you determine any relationship between visibility reduction and relative humidity?
4. Can you determine any relationship between visibility reduction and the levels of air pollution?

Experiment E-7 PARTICULATES AND CLOUD FORMATION

Introduction: When the relative humidity nears 100% in the atmosphere, particles may serve as nuclei or centers and enhance the condensation of water vapor to form clouds or fog. In this experiment, the relative humidity is increased to 100% by creating a partial vacuum over water.

Objective: To demonstrate the effect of suspended particulates on the formation of clouds and fog.

Materials: Two 1-liter Erlenmeyer flasks; 2, 2-hole rubber stoppers (to fit flasks); 3, 4-inch pieces of glass tubing; 1, 8-inch piece of glass tubing; 4 ft. of thick-walled rubber tubing; 3 pinch clamps; safety matches; vacuum pump; cotton balls.

Procedure:

1. Set up the apparatus as shown on the following page using thick-walled rubber tubing rather than thin-walled tubing due to the possibility of collapse.
2. Place approximately 10 ml of water in the bottom of flask #2.
3. Clean Air Test
   a) Insert a ball of cotton into the end of the inlet tubing
   b) Remove all three pinch clamps, and turn on the vacuum pump for 30 seconds
   c) Replace clamps 2 and 3 with the pump running
   d) After 15 seconds, shut off the pump and quickly replace clamp 1
   e) Remove clamp 2 and observe what happens in flask #2.
4. Air Containing Small Particles Test
   a) Remove the cotton ball
   b) Remove all the clamps and turn on the vacuum pump
   c) Hold a lighted match at the inlet for 15 seconds
   d) Quickly replace clamps 2 and 3 and extinguish the match
   e) After an additional 15 seconds, shut off the pump and quickly replace clamp 1
   f) Remove clamp 2 and observe what happens in flask #2.

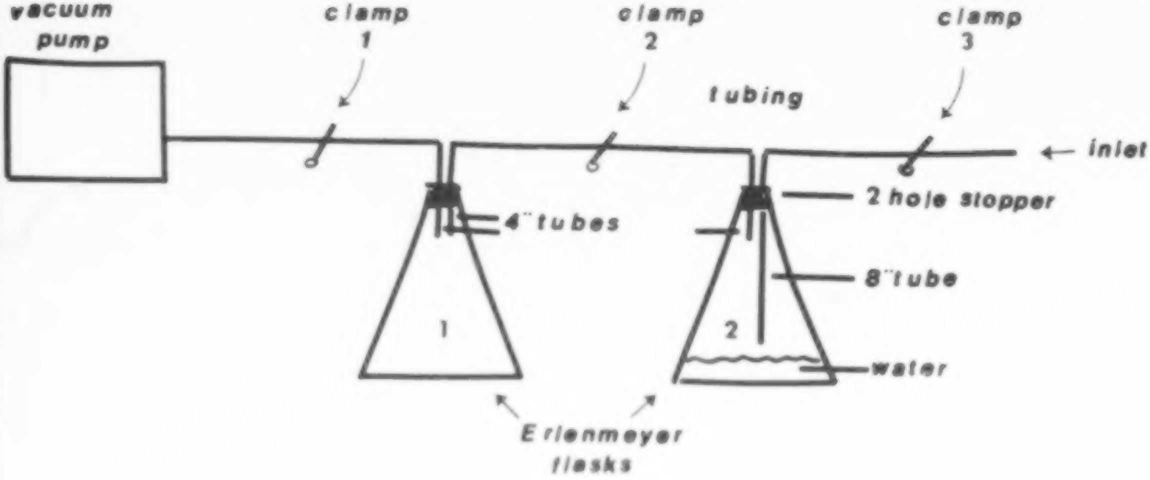
Results: Observe whether a cloud formed in flask #2.

Discussion:

1. Discuss your observations.
2. Why did a fog form when the match was used?

3. Can you think of any reasons why airports should not be located in industrialized areas where there are many emissions of particulates?

4. On many of the hazy, polluted days which occur, fog is present—especially in the morning. Have you ever noticed this? Can you explain it?


vacuum pump
clamp 1
clamp 2
tubing
clamp 3
inlet
4" tubes
2 hole stopper
8" tube
1
2
water
Erlenmeyer flasks

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F. METHODS OF AIR POLLUTION CONTROL

We are constantly exposed to our atmosphere every day. Because we are all contributors to and receptors of air pollution, we have a responsibility to keep it as clean as possible.

The control of air pollution is necessary to prevent air pollutants from contaminating the air in objectionable amounts and also to prevent serious effects from occurring. Because of increased industrial development, urbanization, increased automotive usage, etc., federal, state, and local legislation and regulations were adopted to limit the amount of air pollutants which may be emitted. As a result, control measures are used to keep air pollutant emissions within certain limits. Monitoring of air pollution is done by pollution control agencies and others to measure the amount of air pollution and to determine the effectiveness of the air pollution control measures.

Air pollution can be controlled in several ways:

1. Prevent formation of air pollutants
    a) alter or substitute the fuel or raw materials used (e.g. shift from high sulfur fuel to low sulfur fuel; use natural gas or desulfurized fuel instead of coal or high sulfur fuel; change the formula of the product so that its production produces less pollution)
    b) change the production process (e.g. reduce excess air when burning fossil fuels in order to reduce nitrogen oxides emissions)
    c) change the equipment (e.g. replace an older furnace with one designed for more complete combustion)
    d) improve maintenance and operation procedures (e.g. keep motor vehicles properly tuned and furnaces and incinerators properly adjusted; operate a boiler according to the manufacturer's specifications)
    e) enclose the operation (e.g. use floating roofs rather than fixed roofs over storage tanks of fuel oils and other volatile substances).

2. Dilute the concentrations of air pollutants by improved dispersion
    a) select a site that has good ventilation
    (Weather conditions such as wind speed and inversion height vary considerably from place to place. Consequently, before a polluting plant is constructed, a site with generally good ventilation, strong winds, and infrequent inversions should be chosen. For example, valleys tend to have poor ventilation because frequent low level

inversions and calm winds are common overnight and in the early morning. Such conditions would produce a build-up of pollutants. A windy hilltop or lake shore might be a better site choice.)

b) build taller smokestacks that will dilute the air pollutants by dispersion over a wider area, although the total amount of air pollutants being emitted will remain the same
(It should be mentioned that this method was employed frequently in the past. In recent years, however, it was discovered that in many cases this practice increased concentrations of pollutants many miles downwind of the source.)

3. Collect the air pollutants before they reach the atmosphere
   a) various control devices may be installed to eliminate, collect, or alter the air pollutants. These devices are described in the following paragraphs

Larger particulates may be removed in a settling chamber. Suspended particulates travel rapidly through a narrow duct and enter a larger settling chamber where gravity causes them to fall to the bottom.

Smaller particulates need to be removed by more effective equipment such as inertial collectors. Cyclone collectors are one type of intertial collector in which a stream of suspended air pollutants is rushed into a cylindrical chamber and rotated at high speed. This causes many of the particulates to be thrown onto the chamber's walls from which they fall and can be collected.

Fabric filters will also remove particulates; they are basically giant vacuum cleaners. Suspended air pollutants pass through the fabric which traps the particulates in its fibers.

The most effective (and also very costly) method for trapping and collecting particulates is the electrostatic precipitator which, in ideal situations, can remove 99.9 percent of all the particulate matter that comes in contact with it. As the suspended air pollutants pass through the electrostatic precipitator, the particulates receive an electrical charge. Then, they are attracted toward the oppositely charged collecting tubes or plates where they become neutralized and fall (or are shaken) into the collection hopper.

Water (or some other liquid) sprays also are often used by devices known as scrubbers to assist in the removal of smaller particulates. However, they can create water pollution problems when the contaminated waste liquid is disposed of. There are several kinds of scrubbers involving various techniques which use a liquid to wash out or dissolve pollutants.

Gaseous pollutants are removed by absorption, adsorption, incineration or oxidation, and condensation. In absorption, gaseous pollutants are removed by passing them through a liquid. The gas either dissolves in the liquid or reacts chemically with it.

Adsorption removes certain gaseous pollutants by passing them through a porous solid such as activated carbon. The gas is attracted and adheres to this solid.

In incineration, or oxidation, unburnt hydrocarbons are converted to carbon dioxide and water. The incineration process produces complete combustion by using devices called afterburners which burn the hydrocarbons at high temperatures with thorough mixing and sufficient retention time. Other oxidizing devices are called catalytic converters, the hydrocarbons and carbon monoxide pass over a solid catalyst material which causes them to react with oxygen to form carbon dioxide and water. All late-model American made, gasoline-powered automobiles incorporate this device to reduce their hydrocarbon and carbon monoxide emissions.

In the condensation process, gaseous pollutants are cooled down until they condense into a liquid which is then removed.

Activities

1. As a class project, simulate a town council meeting that has convened to discuss whether to re-zone to allow a new potentially polluting industry to build inside your community's boundaries. Present at this meeting are the town council, industry representatives, union representatives, residents of the area near the proposed plant site, citizens who are concerned about the environment, and business people from the town.
2. Survey several industrial users of oil and coal to determine what type of air pollution control devices are used.
3. Interview a car dealer to determine what pollution control devices are installed in their cars.
4. The open burning of leaves and other materials puts harmful pollutants into the air which may lead to respiratory irritation. Determine if your state or city has legislation which prohibits open burning. If it does, is this legislation enforced?
5. Look around your community and home and list what can be done to decrease air pollution. Is there anything that could be done by you and your family to decrease air pollution?

6. Find out what federal, state, and local agencies are responsible for monitoring the quality of the air and also for enforcing air pollution regulations in your area.

7. If there is an air pollution problem in your area, would a federal, state, or local pollution control agency handle the situation?

8. Prepare a report on the federal government's major air pollution control laws and regulations.

   a) What are the national ambient air quality standards and why were they established?

   b) What are the prevention of significant deterioration regulations?

9. Invite a speaker from your state's air pollution control agency to talk about air pollution control. Determine which areas in your state are meeting the national ambient air quality standards.

10. If an area has achieved attainment status (it is meeting the ambient air quality standards), how does you state determine what new industries can build there? If it is a non-attainment area and is not meeting the ambient air quality standards, find out what procedures an industry must follow before it can construct a new plant.

11. Determine whether your community has local air pollution control ordinances.

12. In order for air pollution control to be effective, it must have the support of the population. Prepare an opinion poll concerning air pollution control and include such topics as

    a) how serious an air pollution problem exists

    b) who is primarily responsible for air pollution

    c) how should air pollution be controlled

    d) are the air pollution regulations sufficient to improve the air

    e) who should be responsible for overseeing air pollution regulations, etc.

References

(1) AMERICAN LUNG ASSOCIATION. "Controlling Air Pollution", New York, NY, 1974.

(2) STERN, A. C. (ed.), Air Pollution, 2 ed., Academic Press, New York, NY, 1968.

(3) WILLIAMSON, S. J. Fundamentals of Air Pollution, Addison-Wesley Pub. Co., Reading, MA, 1973.

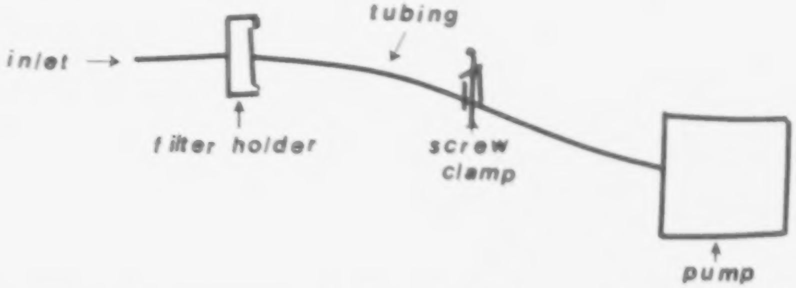
Experiment F:1 POLLUTION CONTROL BY SCRUBBING AND FILTRATION

Objective: To demonstrate two control devices that reduce particulate emissions at the source by employing scrubbers or filters.

Materials: The following equipment used in Experiment C:3 will be needed: vacuum pump; screw clamp; filters; filter holders; Tygon or rubber tubing. In addition, the following equipment will be needed: 1,1-liter Erlenmeyer flask; 1, 1-liter, 2 neck, flat-bottom boiling flask; 2, 1-hole rubber stoppers (to fit necks of boiling flask); 1, 2-hole rubber stopper (to fit neck of Erlenmeyer flask); 4 pieces of glass tubing (2, 6-inch lengths and 2, 3-inch lengths) to fit through the rubber stoppers; several ounces of very dry, finely ground soil or dark powder; glass beads; water; glass wool; teaspoon; dish.

Procedure:

1. Set up the apparatus in the manner shown below. Place a clean piece of filter paper in the filter holder.



2. Place ½ teaspoon of the finely ground soil or powder into a dish.
3. Turn on the pump. As the end of the tubing is placed in the dish, adjust the flow with the screw clamp so that there is sufficient suction to vacuum up the soil or powder from the dish.
4. When all of the particulate matter has been vacuumed up, shut off the pump and remove the filter paper. This represents the "uncontrolled situation." Observe and save the filter.
5. To demonstrate the principle of a scrubber, set up the apparatus in the manner shown on the following page. Put a clean piece of filter paper in the filter holder. The 2, 6-inch glass tubes should be positioned so that they are ½ inch from the bottom of the flasks. The 2 3-inch pieces should protrude no more than ½ inch from the bottom of the stoppers. Add glass beads to the boiling flask so that the top of the beads is at least 1 inch below the end of the 3-inch glass tube. Then, fill with water to this same level.

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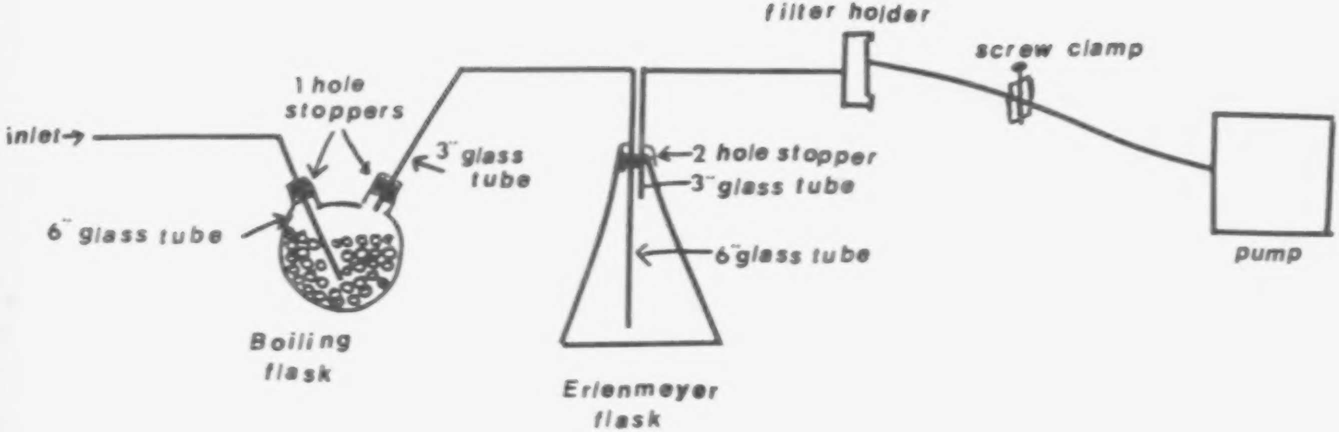
filter holder
screw clamp
1 hole stoppers
inlet→
3" glass tube
2 hole stopper
3" glass tube
6" glass tube
6" glass tube
pump
Boiling flask
Erlenmeyer flask

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6. Repeat Steps 2 to 4. Observe how much particulate matter was removed in the boiling flask ("the scrubber").

7. To demonstrate the principle of filtration, set up the apparatus as in Step 5; however, do not add the water or glass beads. Instead, fill the boiling flask with glass wool.

8. Place a clean piece of filter paper in the filter holder and repeat Steps 2 to 4. Observe how much particulate matter was removed by the glass wool filter.

Results: Compare the amount of particulate matter on each of the three filter papers.

Discussion:

1. Explain why there was less particulate matter on the filter papers obtained in Steps 6 and 8 than in Step 4.
2. In the scrubber, many pollutants were removed by water. How do you dispose of the dirty water without creating a water pollution problem?
3. In filtration, many particulates are removed by a filter material. After a while, the filter will become so dirty that it will clog. When this happens, the filter must either be cleaned or replaced. Which would you do and how would you dispose of the collected particulates?